



2nd INTERNATIONAL

EMERGING SCHOLARS FORUM (IESF-2026)

Emerging Insights for a Resilient Future:
Climate, Equity, and Innovation
in Agri-Food Systems



AUGUST 24–26, 2026



Faisalabad, Pakistan

Research | Dialogue | Impact



ABSTRACT BOOK



SUSTAINABLE
AGRICULTURE



NUTRITION &
FOOD SECURITY



BIODIVERSITY &
ECOSYSTEMS



TECHNOLOGY &
INNOVATION



GREEN FINANCE &
POLICY



RENEWABLE
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LIVESTOCK
ECONOMICS



FOOD SCIENCES
& NUTRITION



AGRIBUSINESS &
VALUE CHAINS

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Abstract Book

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August 24 – 26, 2026

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Muhammad Khalid Bashir^{1,*}, Mithat Direk², Mustafa Kan³, Asghar Ali¹ & Muhammad Hafeez⁴

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Foreword — Message from the Patron-in-Chief

It gives me immense pleasure to extend my warmest greetings to the organizers, researchers, scholars, policymakers, and participants of the 2nd International Emerging Scholars Forum (IESF-2026). Building upon the achievements of its inaugural edition, this forum represents an important platform for emerging scholars to exchange knowledge, challenge conventional thinking, and contribute innovative ideas to the development of resilient, inclusive, and sustainable agri-food systems.

Agriculture and food systems are facing unprecedented challenges arising from climate change, environmental degradation, resource scarcity, market volatility, technological transformation, and evolving socioeconomic conditions. These challenges are particularly significant for developing and climate-vulnerable countries, where agricultural livelihoods, food security, and rural economies remain closely connected. Addressing them requires not only technological advancement but also sound economic analysis, effective institutions, inclusive policies, and strong collaboration among academia, government, industry, and communities.

IESF-2026 provides a timely opportunity to explore these interconnected challenges through an interdisciplinary perspective. The forum's focus on climate-smart agriculture, the water–energy–food nexus, carbon markets, green innovation, ecosystem services, and environmental sustainability reflect the growing need for evidence-based approaches to resource management and climate resilience. Equally important is its attention to structural transformation, value-chain resilience, digital agriculture, trade, market integration, food security, nutrition, and rural livelihoods.

The rapid advancement of artificial intelligence, remote sensing, big data analytics, blockchain, and other digital technologies is creating new opportunities for agricultural transformation. However, technological progress must be accompanied by responsible governance, equitable access, data protection, and ethical considerations. Ensuring that smallholders, women, rural communities, and other vulnerable groups benefit from these innovations should remain central to the development of future agri-food systems.

I particularly appreciate the forum's emphasis on policy and institutional innovation. Issues such as land tenure, gender equity, labor mobility, governance, indigenous knowledge, and community-led adaptation demonstrate that sustainable development cannot be achieved through technology alone. Strong institutions and inclusive policy frameworks are essential for translating research findings into meaningful improvements in the lives and livelihoods of farming and rural communities.

The methodological diversity promoted by IESF-2026 is equally commendable. The integration of advanced quantitative methods, experimental and behavioral approaches, life-cycle assessment, and mixed-method research can generate deeper and more policy-relevant understanding of complex agricultural and environmental challenges. Such interdisciplinary scholarship is essential for bridging the gap between academic research and practical development needs.

As a leading institution in agricultural education, research, and innovation, the University of Agriculture, Faisalabad recognizes the importance of nurturing young researchers and creating opportunities for them to engage with global scientific communities. Forums such as IESF provide emerging scholars with a valuable space to present their work, receive constructive feedback, establish professional networks, and develop research that can contribute to national, regional, and global development priorities.

I am confident that the discussions, research contributions, and collaborations emerging from IESF-2026 will strengthen research–policy linkages and inspire innovative solutions for sustainable agri-food systems. I encourage all participants to engage openly, think critically, collaborate across disciplines, and ensure that their research remains responsive to the needs of society, particularly those communities most vulnerable to climate and economic shocks.

I extend my sincere appreciation to the organizing committee, academic contributors, partner institutions, and all emerging scholars whose efforts have made this forum possible. I wish IESF-2026 every success and hope that its outcomes will contribute meaningfully to a more resilient, inclusive, sustainable, and food-secure future.

Prof. Dr. Zulfiqar Ali

Patron-in-Chief, IESF-2026

Vice Chancellor

University of Agriculture, Faisalabad, Pakistan

Message from the Conference Chair / Convener

It is my great pleasure to welcome researchers, scholars, policymakers, practitioners, and emerging academics to the 2nd International Emerging Scholars Forum (IESF-2026). Following the encouraging success of the inaugural forum, IESF-2026 provides another opportunity to bring together emerging scholarly voices to engage with some of the most pressing challenges confronting agriculture, natural resources, rural economies, and agri-food systems.

The global agri-food system is undergoing profound transformation. Climate change, environmental degradation, resource scarcity, market uncertainty, technological disruption, and changing socioeconomic conditions are reshaping agricultural production, food security, rural livelihoods, and development pathways. These challenges are particularly significant for developing and climate-vulnerable economies, where agriculture remains central to employment, livelihoods, and national economic development. Addressing these interconnected challenges requires innovative research that combines rigorous economic analysis with insights from environmental science, technology, social sciences, and development policy.

IESF-2026 has therefore been designed around a broad and interdisciplinary research agenda. The forum provides a platform for examining climate-smart agriculture, the water–energy–food nexus, carbon markets, ecosystem services, green innovation, environmental sustainability, and climate resilience. At the same time, it explores structural transformation within agri-food systems through research on value chains, digital agriculture, market integration, trade, food security, nutrition, rural livelihoods, and behavioral change.

Technological innovation represents another important dimension of this year's forum. Artificial intelligence, remote sensing, big data, blockchain, and digital platforms are creating new possibilities for improving productivity, resource efficiency, market access, and transparency. However, technological transformation also raises important questions concerning digital inequality, data governance, ethical use, affordability, and the inclusion of smallholder farmers. IESF-2026 encourages researchers to examine both the opportunities and limitations of these emerging technologies.

The forum also recognizes that sustainable transformation depends fundamentally on institutions and public policy. Land tenure, gender equity, labor mobility, governance, institutional reform, and community participation are essential components of inclusive development. Particular attention to Global South perspectives, indigenous knowledge, and community-led adaptation can help ensure that development strategies are locally relevant and socially inclusive.

As Conference Chair, I am especially pleased to see the emphasis placed on methodological innovation. The use of advanced econometric techniques, experimental and behavioral methods, life-cycle assessment, and mixed-method approaches can generate stronger evidence for policy and practice. More importantly, interdisciplinary research can help bridge the longstanding gap between academic knowledge and real-world development challenges.

IESF-2026 is intended not simply as a platform for presenting research, but as a space for dialogue, collaboration, learning, and mentorship. I encourage emerging scholars to use this opportunity to engage critically with fellow researchers, receive constructive feedback, establish lasting academic networks, and explore collaborative research opportunities. I also hope that senior researchers, policymakers, and practitioners will support and mentor the next generation of scholars.

I sincerely appreciate the commitment of the organizing committee, reviewers, academic contributors, partner institutions, and participants whose collective efforts have made this forum possible. Their dedication reflects a shared commitment to advancing knowledge and promoting evidence-based solutions for sustainable agricultural and rural development.

I warmly welcome all participants to IESF-2026 and look forward to an intellectually stimulating and productive forum. May the research presented, discussions held, and partnerships developed during this event contribute to more resilient, inclusive, sustainable, and equitable agri-food systems.

Dr. Muhammad Khalid Bashir

Conference Chair, IESF-2026

Associate Professor (Tenured)

Institute of Agricultural and Resource Economics

University of Agriculture, Faisalabad, Pakistan

About IESF-2026

The International Emerging Scholars Forum (IESF) is an interdisciplinary academic platform established to provide emerging scholars with a meaningful space to present their research, exchange ideas, receive constructive academic feedback, and develop professional networks. The forum recognizes that the next generation of researchers will play a critical role in addressing complex agricultural, economic, environmental, technological, and development challenges. By bringing together researchers from diverse academic and geographical backgrounds, IESF seeks to encourage intellectual exchange beyond disciplinary boundaries and promote research that is both academically rigorous and relevant to real-world development challenges.

At its core, IESF is committed to strengthening the connection between research, policy, and development practice. The forum encourages young and emerging researchers to move beyond conventional disciplinary perspectives and examine contemporary issues through integrated economic, social, environmental, technological, and institutional lenses. Particular emphasis is placed on research that can contribute to evidence-based policymaking, sustainable resource management, resilient agricultural systems, inclusive rural development, food security, and improved livelihoods. The forum also provides an opportunity for emerging scholars to engage with experienced academics, policymakers, practitioners, and other stakeholders, thereby strengthening mentorship, collaboration, and knowledge exchange.

The 2nd International Emerging Scholars Forum (IESF-2026) builds upon the encouraging experience and achievements of its inaugural edition. The 2026 edition is being organized at a time when agri-food systems are experiencing rapid and interconnected transformations. Climate change, environmental degradation, resource scarcity, market volatility, geopolitical uncertainty, technological disruption, and changing patterns of production and consumption are creating new challenges for agriculture and rural economies. These pressures are particularly significant for developing and climate-vulnerable countries, where agriculture remains closely linked with employment, food security, rural livelihoods, and broader economic development. IESF-2026 therefore provides a timely platform for emerging scholars to examine these challenges and develop innovative, evidence-based responses.

The thematic scope of IESF-2026 reflects the multidimensional nature of contemporary agri-food and development challenges. The forum highlights research on climate-smart agriculture, the water–energy–food nexus, carbon markets, green innovation, ecosystem services, environmental sustainability, value-chain resilience, digital agriculture, trade and market integration, food security, nutrition, and rural transformation. It also emphasizes emerging technologies, including artificial intelligence, remote sensing, big data analytics, and blockchain, while encouraging critical discussion of digital inequality, data governance, ethical considerations, and smallholder inclusion. Alongside technological and economic transformation, the forum gives importance to institutional and policy dimensions, including governance reforms, land tenure, gender equity, labor mobility, indigenous knowledge, and community-led adaptation.

IESF-2026 also seeks to promote methodological innovation and interdisciplinary scholarship. Contributions employing advanced quantitative and econometric techniques, experimental and behavioral approaches, life-cycle assessment, mixed-method research, and integrated economic, social, and ecological frameworks are particularly encouraged. The ultimate mission of the forum is not simply to showcase emerging research but to create a productive environment in which ideas can be challenged, refined, connected, and translated into meaningful policy and development insights. Through scholarly dialogue, collaboration, mentorship, and research-policy engagement, IESF-2026 aims to empower the next generation of scholars and contribute to resilient, inclusive, sustainable, and transformative agri-food systems, particularly across developing and climate-vulnerable regions.

Conference Sub-Themes

- 1. Climate Resilience and Sustainable Resource Economics
- 2. Agri-Food System Transformation and Market Dynamics
- 3. Technology and Data-Driven Agriculture
- 4. Equity, Policy, and Institutional Innovation
- 5. Emerging Methodologies and Interdisciplinary Approaches
- 6. Livestock Economics and Sustainable Animal Systems
- 7. Food Sciences and Nutrition Systems
- 8. Agricultural Engineering and Smart Systems
- 9. Agribusiness, Entrepreneurship, and Value Chain Development

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Keynote & Panel Speakers

The Forum features a dedicated Keynote Addresses & Panel Discussion session on Day 2 (August 25, 2026), 11:45 AM – 1:15 PM PKT.

Speaker 1

Prof. Martin Spraggon, Executive Director of the Industry Engagement Center, Abu Dhabi School of Management, UAE

Topic: Agricultural Engineering and Smart Systems

Speaker 2

Prof. Dr. Rizwan Yaseen, Chairman, Department of Economics, GC University Faisalabad, Pakistan

Topic: Towards Sustainable Agriculture: Policy and Economic Perspectives on Hydroponic Tomato Farming in Pakistan

Speaker 3

Prof. Florian Marcel Nuță, Danubius International University, Romania

Topic: Emerging Methodologies and Interdisciplinary Approaches

Speaker 4

Prof. Rui Alexandre Castanho, Vice-Dean for Sustainable Development at the WSB University, Poland
European Climate Pact Ambassador.

Topic: Agricultural Engineering and Smart Systems

Speaker 5 Pannel Discussion

Dr. Arman Khanzada, Director ORIC, Shaheed Benazir Bhutto University, Nawabshah, Pakistan.

Topic: Agri-Food System Transformation and Market Dynamics

Speaker 6 Pannel Discussion

Dr. Fayaz Hussain Tunio, The Shaheed Zulfiqar Ali Bhutto University of Law (SZABUL), Pakistan

Topic: Equity, Policy, and Institutional Innovation

Speaker 7 Pannel Discussion

Dr. Muhammad Arif, Chairman, Department of Business Administration, Shaheed Benazir Bhutto University, Pakistan.

Topic: Technology and Data-Driven Agriculture

Speaker 8 Pannel Discussion

Dr. Shamrez Ali, Department of Economics, University of Sargodha, Pakistan

Topic: Climate Resilience and Sustainable Resource Economics

Speaker 9 Pannel Discussion

Dr. Muhammad Tayab Tahir, National Business School, The University of Faisalabad, Pakistan

Topic: Agribusiness, Entrepreneurship, and Value Chain Development

SECTION I

1. Climate Resilience and Sustainable Resource Economics

33 Abstracts

Ameliorating Adverse Effects of Drought on Growth and Yield of Pearl Millet (*Pennisetum glaucum* (L.) R. Br) by Foliar Application of Commercial Salicylic Acid.

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1. Introduction

Pearl millet (*Pennisetum glaucum* L.) is a drought-tolerant cereal crop widely cultivated for human consumption and livestock feed due to its high nutritional value. However, prolonged drought stress significantly reduces plant growth, physiological performance, and grain yield, posing a major challenge to sustainable crop production under changing climatic conditions. Salicylic acid (SA), an important plant signaling molecule, has been recognized for its role in enhancing tolerance to abiotic stresses by regulating physiological and biochemical processes. This study investigates the potential of foliar-applied salicylic acid to improve drought tolerance and productivity in pearl millet.

2. Objectives

The study aimed to evaluate the effectiveness of exogenous salicylic acid in mitigating drought-induced physiological, biochemical, and yield losses in two pearl millet varieties by enhancing antioxidant defense mechanisms and improving plant performance.

3. Methodology

A field experiment was conducted at Bahauddin Zakariya University, Multan, using two pearl millet varieties, Kamar Masani and Rujhan. Four treatments were evaluated: control, control + salicylic acid, drought stress, and drought stress + salicylic acid. A 1 mM salicylic acid solution was applied as a foliar spray at the onset of mild wilting. Growth, yield, chlorophyll content, total soluble protein, antioxidant enzyme activity, hydrogen peroxide (H₂O₂), and malondialdehyde (MDA) levels were measured.

4. Results

Drought stress significantly reduced plant growth, grain yield, chlorophyll content, and total soluble protein while increasing oxidative stress indicators (H₂O₂ and MDA). Foliar application of 1 mM salicylic acid effectively alleviated drought damage by improving growth and yield attributes, enhancing chlorophyll content, total soluble protein, and superoxide dismutase (SOD) activity, and reducing oxidative damage in both pearl millet varieties.

5. Conclusion & Recommendations

Foliar application of salicylic acid is an effective and economical strategy for enhancing drought tolerance in pearl millet by strengthening antioxidant defense systems and maintaining physiological stability. Its adoption in drought-prone regions can improve crop resilience, sustain productivity, and support climate-smart agricultural practices. Further multi-location field evaluations are recommended to optimize application rates under diverse environmental conditions.

Keywords: *Pennisetum glaucum*; drought stress; salicylic acid; antioxidant enzymes; growth; yield; climate-smart agriculture.

Optimizing Insecticide Input Efficiency for Climate-Resilient Maize Production: A Bioassay of Novel Binary Formulations Against *Spodoptera frugiperda*

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1. Introduction

The fall armyworm (*Spodoptera frugiperda*) is one of the most destructive invasive pests threatening global maize production, with its rapid spread accelerated by climate change. Since its emergence in Punjab, Pakistan, in 2019, it has posed a significant challenge to food security and sustainable crop production. Improving insecticide efficacy and input efficiency is essential for developing climate-resilient pest management strategies while minimizing environmental risks and delaying insecticide resistance. This study evaluates the performance of commercially available binary insecticide formulations against *S. frugiperda* under laboratory and field conditions.

2. Objectives

The study aimed to compare the bioefficacy of seven commercial binary insecticide formulations against *S. frugiperda* and identify efficient products and application rates for sustainable, climate-resilient maize production and resistance management.

3. Methodology

Laboratory bioassays evaluated seven binary insecticide formulations against third-, fourth-, and fifth-instar larvae using five concentrations (0.25×–4× the recommended field rate) through the leaf-dip method in a completely randomized design. A field experiment employing a factorial randomized complete block design assessed larval population reduction and leaf damage at 3, 7, and 14 days after application. Mortality responses were analyzed using Probit analysis.

4. Results

Both insecticide formulation and concentration significantly influenced larval mortality ($p < 0.001$). Astris Gold and Taragen exhibited the greatest efficacy, with the lowest LC_{50} values and effective control across all larval instars. Surviving larvae showed reduced growth, pupation, and adult emergence, indicating strong sublethal effects. Under field conditions, optimized application rates achieved approximately 92% larval reduction and 90% leaf damage reduction within 14 days, demonstrating high pest control efficiency with lower insecticide inputs.

5. Conclusion & Recommendations

Chlorantraniliprole-based binary formulations, particularly Astris Gold and Taragen, provide effective and resource-efficient control of *S. frugiperda*. Their adoption can reduce insecticide use, delay resistance development, and enhance the climate resilience of maize production systems. Further multi-location validation is recommended to support sustainable integrated pest management strategies.

Keywords: Fall armyworm; *Spodoptera frugiperda*; binary insecticide formulations; bioefficacy; climate-resilient pest management; insecticide efficiency; maize.

Valorization of Agricultural Crop Residues for Climate-Resilient and Sustainable Rural Solid Fuel Production

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1. Introduction

Pakistan generates large quantities of agricultural crop residues annually, yet their utilization remains inefficient because of low bulk density, poor handling characteristics, and limited processing technologies. Consequently, open-field burning is widely practiced, contributing to air pollution, smog, greenhouse gas emissions, and climate change. Converting agricultural residues into charcoal briquettes offers a sustainable solution by transforming biomass waste into clean, value-added solid fuel while reducing environmental degradation and supporting climate-resilient rural energy systems.

2. Objectives

The study aimed to develop a cost-effective briquetting system for converting agricultural crop residues into charcoal briquettes and identify the most suitable biomass feedstock and binder combinations for producing high-quality, sustainable solid fuel.

3. Methodology

Agricultural residues, including rice husk, sugarcane bagasse, wheat straw, and cotton sticks, were carbonized using a locally designed drum kiln and compressed into briquettes with a manually operated briquetting machine. Different binders, including starch, molasses, sugarcane scum, and clay, were evaluated. The briquettes were tested for charcoal yield, bulk density, moisture content, durability, compressive strength, calorific value, ash content, burning time, and machine productivity.

4. Results

Cotton sticks produced the highest charcoal yield (30.27%), followed by sugarcane bagasse (27.54%), rice husk (21.48%), and wheat straw (20.91%). Briquettes prepared with 15% starch binder demonstrated superior performance, achieving a bulk density of 497 kg m⁻³, durability of 82.4%, compressive strength of 1.76 MPa, calorific value of 29.63 MJ kg⁻¹, burning time of 138 minutes, and ash content of 6.18%. The manually operated machine produced 6.1 kg h⁻¹ of briquettes without requiring electrical power.

5. Conclusion & Recommendations

The developed briquetting system provides an affordable and environmentally sustainable approach for converting agricultural residues into high-quality solid fuel. Promoting this technology can reduce open-field burning, improve rural energy security, enhance resource efficiency, and support climate-resilient agricultural development. Wider adoption should be encouraged through technical support, farmer training, and policies promoting biomass-based renewable energy.

Keywords: Agricultural residues; charcoal briquettes; climate resilience; rural energy; biomass valorization; renewable energy; resource efficiency.

Macroeconomic Determinants of Industrial Growth in Pakistan: Evidence from the ARDL Approach (2001–2024)

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1. Introduction

Industrial growth is a key driver of sustainable economic development, contributing to employment generation, productivity enhancement, investment, and structural transformation. In Pakistan, however, industrial performance has been constrained by macroeconomic instability, inflationary pressures, and structural challenges that have limited long-term growth. Understanding the macroeconomic factors influencing industrial development is essential for designing effective policies that enhance competitiveness and promote sustainable economic progress. This study investigates the effects of selected macroeconomic determinants on industrial growth in Pakistan using annual time-series data from 2001 to 2024.

2. Objectives

The study aims to examine the short-run and long-run impacts of selected macroeconomic variables on industrial growth in Pakistan and provide evidence-based policy recommendations to strengthen industrial performance and sustainable economic development.

3. Methodology

A quantitative research design was employed using annual secondary data for the period 2001–2024 obtained from reliable national and international sources. The Augmented Dickey–Fuller (ADF) unit root test was applied to determine the stationarity of the variables. The Auto-Regressive Distributed Lag (ARDL) model was used to estimate both short-run dynamics and long-run relationships between industrial growth and key macroeconomic determinants.

4. Results

The findings reveal that Gross Domestic Product (GDP), Industrial Value Added (IVA), inflation, and trade openness exert positive and statistically significant effects on industrial growth. The ARDL model confirms a stable long-run equilibrium relationship among the variables while capturing short-run adjustments. The results highlight the importance of macroeconomic stability, investment, and trade liberalization in improving industrial productivity and supporting sustainable industrial development.

5. Conclusion & Recommendations

Sustained industrial growth in Pakistan requires stable macroeconomic policies, increased public and private investment, supportive trade policies, reliable energy supply, and consistent industrial policy implementation. Strengthening these areas will enhance industrial competitiveness, promote productivity, and contribute to long-term economic growth and sustainable development.

Keywords: Industrial growth; Pakistan; ARDL model; macroeconomic determinants; sustainable economic growth; industrial development.

Socio Economic Factors Influencing High School Dropouts in District Mianwali, Punjabi, Pakistan

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1. Introduction

School dropout remains a major educational and socioeconomic challenge in Pakistan, which has one of the world's largest populations of out-of-school children. High dropout rates undermine human capital development, increase poverty, and limit opportunities for sustainable economic growth. While previous studies have examined individual and school-related determinants, limited evidence exists on the influence of parental socioeconomic and demographic characteristics in rural districts. This study investigates the key socioeconomic factors affecting high school dropout in District Mianwali, Punjab, Pakistan.

2. Objectives

The study aims to identify the socioeconomic, demographic, and educational factors influencing high school dropout and assess the role of household characteristics, parental education, and school accessibility in shaping students' retention in rural areas.

3. Methodology

A mixed-methods research design was employed using primary data collected from households across different tehsils of District Mianwali through an appropriate sampling technique. Quantitative data were analyzed using the Statistical Package for the Social Sciences (SPSS) to identify the major determinants of school dropout, while qualitative information provided contextual understanding of household and educational challenges.

4. Results

The findings reveal that teacher availability, parental education, and higher household income significantly reduce the likelihood of school dropout. Household income decreased the probability of dropout by approximately 69.3%, highlighting its protective role. In contrast, larger family size, child labor, and greater distance to school significantly increased dropout risk, with child labor emerging as the strongest determinant, making students approximately 23.6 times more likely to leave school. These results underscore the combined influence of socioeconomic conditions and educational access on school retention.

5. Conclusion & Recommendations

Reducing school dropout in rural Pakistan requires integrated policies that address both economic and educational barriers. Conditional cash transfer programs, financial support for low-income households, parental literacy initiatives, strengthened child labor enforcement, and improved access to quality schools are recommended to enhance educational equity, increase school retention, and promote sustainable human capital development.

Keywords: Education; school dropout; parental income; socioeconomic factors; child labor; educational access; Pakistan.

Impact of Climate Change and Human Development: Resilience as a Strategy for Adaption

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1. Introduction

Climate change poses a significant threat to human development by affecting livelihoods, health, food security, water resources, energy systems, and biodiversity. Although Pakistan contributes minimally to global greenhouse gas emissions, it is among the countries most vulnerable to climate-related hazards such as floods, droughts, and extreme temperatures. These challenges undermine socioeconomic development and increase vulnerability, particularly in Punjab. Building resilience through adaptive capacity has therefore become essential for minimizing climate risks and ensuring sustainable human development. This study investigates the relationship between climate change and human development while highlighting resilience as a strategic approach to climate adaptation.

2. Objectives

The study aims to assess the impact of climate change on human development in Punjab, Pakistan, and examine how resilience-based strategies can strengthen adaptive capacity and reduce climate-related vulnerabilities at individual and community levels.

3. Methodology

The research consists of two complementary components. First, annual data from 1990–2024 obtained from the Global Data Lab were analyzed using the Autoregressive Distributed Lag (ARDL) model to estimate the long-run and short-run effects of climate variables on human development. Second, a resilience framework was developed through a review of adaptation literature and practical interventions to identify strategies that enhance social cohesion, adaptive capacity, and community resilience.

4. Results

The empirical findings reveal a significant negative relationship between climate change and human development in Punjab. Climate variability adversely affects livelihoods, food and water security, and overall well-being. The resilience framework demonstrates that strengthening adaptive systems through community participation, institutional support, social cohesion, and inclusive development interventions enhances the capacity of vulnerable populations to respond effectively to climate-related risks.

5. Conclusion & Recommendations

Climate change poses a substantial challenge to sustainable human development in Punjab. Integrating resilience into climate and development policies is essential for reducing vulnerability and improving adaptive capacity. Policymakers should strengthen climate-resilient infrastructure, promote community-based adaptation, invest in education and institutional capacity, and implement inclusive climate policies to safeguard long-term human development.

Keywords: Climate change; resilience; human development; adaptation; Punjab; Pakistan.

Comparative Analysis of Insecticides Effects on Lynx Spider (*OXYOPUS JAVANUS*) Populations

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1. Introduction

Natural enemies play a crucial role in biological pest control and maintaining ecological balance in agricultural ecosystems. However, indiscriminate insecticide use can negatively affect beneficial arthropods through lethal and sublethal effects, thereby reducing the effectiveness of biological control and Integrated Pest Management (IPM). The lynx spider (*Oxyopes javanus*) is an important generalist predator that suppresses a wide range of crop pests. Evaluating the compatibility of commonly used insecticides with this beneficial predator is essential for developing environmentally sustainable pest management strategies.

2. Objectives

The study aimed to compare the lethal and sublethal effects of deltamethrin, thiacloprid, and spirotetramat on *Oxyopes javanus* by assessing acute toxicity and locomotor performance to identify insecticides compatible with biological control and sustainable IPM programs.

3. Methodology

Laboratory bioassays were conducted using four concentrations of each insecticide (recommended field rate, $\frac{1}{2}$, $\frac{1}{4}$, and $\frac{1}{8}$ field rate) and a distilled water control. Mortality was recorded at 4-hour intervals over 48 hours, and LC_{50} values were estimated using probit analysis. Sublethal effects were assessed at LC_{30} concentrations by measuring climbing velocity. Data were analyzed using chi-square tests and one-way ANOVA at a 5% significance level.

4. Results

All tested insecticides significantly increased mortality and reduced locomotor activity in *Oxyopes javanus*. Deltamethrin was the most toxic ($LC_{50} = 296.243 \mu\text{L L}^{-1}$), followed by thiacloprid ($1315.60 \mu\text{L L}^{-1}$) and spirotetramat ($1637.32 \mu\text{L L}^{-1}$). Broad-spectrum insecticides caused significantly greater mortality and behavioral impairment than spirotetramat. Climbing velocity declined significantly in all treated spiders, with deltamethrin producing the greatest adverse effects.

5. Conclusion & Recommendations

Spirotetramat was comparatively safer for *Oxyopes javanus*, whereas deltamethrin posed the greatest risk to this beneficial predator. Selective insecticides should be prioritized within IPM programs to conserve natural enemies and strengthen biological pest control. Further research should investigate the molecular and long-term sublethal effects of insecticides on *Oxyopes javanus* to support sustainable crop protection strategies.

Keywords: *Oxyopes javanus*; spirotetramat; thiacloprid; deltamethrin; biological control; integrated pest management.

Securing the Nexus: Climate Economics for Water, Energy, and Agriculture

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1. Introduction

Climate change is intensifying pressure on interconnected water, energy, and agricultural systems, creating significant challenges for sustainable resource management and economic development. Conventional sector-specific policies often overlook the interdependencies within the Water–Energy–Food (WEF) nexus, resulting in unintended trade-offs, resource inefficiencies, and increased climate vulnerability. An integrated climate-economic framework is therefore essential for balancing competing demands, strengthening resilience, and ensuring long-term sustainability. This study explores a holistic approach to optimizing resource allocation across the WEF nexus under changing climatic conditions.

2. Objectives

The study aims to develop an integrated climate-economic framework for the Water–Energy–Food nexus, evaluate the impacts of climate variability on interconnected resource systems, and identify policy strategies that enhance resilience, resource efficiency, and sustainable economic development.

3. Methodology

A multi-sectoral computable general equilibrium modeling framework was employed to simulate the macroeconomic impacts of altered hydrological conditions, prolonged droughts, and extreme climate events under different climate scenarios. The framework evaluated trade-offs among food security, renewable energy transition, and freshwater conservation while assessing the effectiveness of coordinated policy interventions, including flexible market price mechanisms and technology-based incentives.

4. Results

The analysis demonstrates that isolated sectoral policies are insufficient to address systemic climate risks across the WEF nexus. Coordinated policy packages combining market-based pricing mechanisms with technological innovations significantly improve resource allocation, reduce cross-sector externalities, and strengthen resilience. Integrated investments in water infrastructure, renewable energy, and climate-smart agriculture generate greater economic efficiency, enhance environmental sustainability, and improve long-term food and water security under changing climate conditions.

5. Conclusion & Recommendations

Building climate resilience requires integrated governance rather than fragmented sectoral planning. Policymakers should adopt coordinated investment strategies that simultaneously support water infrastructure, renewable energy development, and climate-smart agriculture. Strengthening cross-sector collaboration, implementing flexible market-based policies, and promoting integrated resource planning will improve economic resilience, optimize public investment, and advance sustainable development in the face of increasing climate uncertainty.

Keywords: Climate economics; Water–Energy–Food (WEF) nexus; climate resilience; resource allocation; sustainable development; renewable energy; climate-smart agriculture.

Sustainable Food Systems: Integrating Nutrition Security and Environmental Resilience

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1. Introduction

Sustainable food systems are fundamental to achieving food and nutrition security while conserving natural resources and enhancing resilience to climate change. Increasing population growth, environmental degradation, soil depletion, water scarcity, and changing dietary patterns have intensified the need for integrated approaches that simultaneously promote agricultural sustainability and public health. Practices such as climate-smart agriculture, agroecology, crop diversification, organic farming, and food waste reduction contribute to resilient food systems by enhancing ecosystem services, biodiversity, and resource-use efficiency. Integrating nutrient-rich diets with environmentally sustainable production systems is essential for improving human well-being and supporting long-term sustainable development.

2. Objectives

The study aims to examine strategies for integrating nutrition security with environmental resilience through sustainable food systems and to identify policy and technological interventions that improve food quality, ecosystem sustainability, and public health outcomes.

3. Methodology

The study employed a comprehensive narrative review of recent scientific literature, international policy reports, and evidence on sustainable agriculture, nutrition, and environmental management. Comparative analysis was conducted to evaluate the effectiveness of climate-smart agriculture, agroecological practices, crop diversification, plant-based diets, biofortified crops, functional foods, and food waste reduction strategies in enhancing food system sustainability and resilience.

4. Results

The review indicated that integrating sustainable agricultural practices with nutrition-sensitive interventions improved food availability, dietary diversity, ecosystem health, and climate resilience. Climate-smart agriculture, diversified cropping systems, plant-based diets, and biofortified crops contribute to reduced greenhouse gas emissions, improved soil fertility, enhanced biodiversity, and better nutritional outcomes. However, limited policy implementation, socioeconomic inequalities, and technological constraints continue to hinder large-scale adoption, particularly in low- and middle-income countries.

5. Conclusion & Recommendations

Developing sustainable food systems requires coordinated policies that integrate agriculture, nutrition, environmental conservation, and public health. Governments should promote climate-smart farming, support nutrition-sensitive agriculture, reduce food loss and waste, strengthen local food systems, and encourage interdisciplinary research and stakeholder collaboration. These measures will improve nutrition security, environmental resilience, and sustainable development while safeguarding both human and planetary health.

Keywords: Sustainable food systems; nutrition security; climate-smart agriculture; environmental resilience; plant-based diets; food waste reduction; public health.

Analyzing the Drivers toward the Adoption of Solar Energy Technology among Households in Pakistan: A Case Study of Gojra

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1. Introduction

Pakistan faces persistent energy shortages despite having substantial solar energy potential. Expanding household adoption of solar energy technologies can enhance energy security, reduce dependence on fossil fuels, lower greenhouse gas emissions, and promote sustainable development. However, the adoption of residential solar systems is influenced by multiple behavioral, social, and technological factors. Understanding these determinants is essential for designing effective policies that encourage the transition toward renewable energy. This study investigates the key factors influencing households' intentions to adopt solar energy technology in Gojra, Pakistan.

2. Objectives

The study aims to identify the behavioral and technological drivers influencing household adoption of solar energy technology and examine the relationships among attitudes, perceived usefulness, perceived ease of use, subjective norms, perceived behavioral control, and adoption intentions.

3. Methodology

Primary data were collected from 269 households in Gojra using a structured questionnaire. The study employed Partial Least Squares Structural Equation Modeling (PLS-SEM) to analyze the relationships among the study variables. The model assessed the effects of attitude toward use, perceived usefulness, perceived ease of use, subjective norms, and perceived behavioral control on households' intentions to adopt solar energy technology.

4. Results

The findings indicate that attitude toward use, perceived usefulness, perceived ease of use, subjective norms, and perceived behavioral control significantly influence households' intentions to adopt solar energy technology. Attitude, subjective norms, and perceived behavioral control exhibited positive direct effects on adoption intention, while perceived usefulness and perceived ease of use positively influenced attitude toward solar technology. Furthermore, perceived behavioral control significantly enhanced perceived usefulness, highlighting the importance of users' confidence and accessibility in encouraging adoption.

5. Conclusion & Recommendations

Behavioral, social, and technological factors play a critical role in promoting household solar energy adoption. Policymakers should strengthen public awareness campaigns, improve the accessibility and ease of solar technologies, expand financial incentives, and encourage community-based promotion of renewable energy. These measures will accelerate household adoption, improve energy security, and support Pakistan's transition toward sustainable and low-carbon development.

Keywords: Solar energy technology; household adoption; renewable energy; PLS-SEM; perceived behavioral control; sustainable energy; Pakistan.

Impact of Climate Change on Wheat Productivity and Farmer's Livelihoods in Punjab: The Case Study of Faisalabad

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1. Introduction

Climate change has become a major challenge to agricultural sustainability, threatening wheat productivity, food security, and rural livelihoods in Pakistan. Rising temperatures, changing rainfall patterns, and increasing climate variability have intensified production risks, particularly for smallholder farmers. Understanding the impacts of climate change on wheat production and household livelihoods is essential for developing effective adaptation strategies and strengthening agricultural resilience. This study assesses the effects of climate change on wheat productivity and the livelihoods of wheat-growing farmers in Tehsil Samundri, District Faisalabad, Punjab, Pakistan.

2. Objectives

The study aims to evaluate the impact of climate change on wheat productivity and farmers' livelihoods and identify adaptation measures and policy interventions that enhance agricultural resilience and rural income stability.

3. Methodology

Primary data were collected from 125 wheat-growing households using a multistage stratified random sampling technique and a structured questionnaire. Descriptive statistics were used to summarize farmers' socioeconomic characteristics and climate perceptions. The General Linear Model (GLM) was applied to examine the determinants of wheat productivity, while Binary Logistic Regression (BLR) was used to assess the effects of climate change on household livelihoods and income.

4. Results

The findings show that 69.6% of farmers perceived rising temperatures, while 68.0% reported declining rainfall and 31.2% experienced irregular rainfall patterns. GLM results indicate that machinery operation and maintenance costs, fertilizer use, and perceived temperature increase significantly influenced wheat productivity. Irregular rainfall showed no significant effect due to irrigation availability. BLR analysis revealed that although farmers adopted adaptation measures to sustain wheat production, increased production costs reduced net income and heightened income variability. Limited access to institutional credit, inadequate extension services, and slow adoption of climate-smart technologies further increased farmers' vulnerability.

5. Conclusion & Recommendations

Climate change continues to threaten wheat production and rural livelihoods despite farmers' adaptation efforts. Strengthening climate-smart agricultural extension services, promoting climate-resilient wheat varieties, improving irrigation management, and expanding access to affordable institutional credit are essential for enhancing agricultural productivity, livelihood resilience, and sustainable rural development in Punjab.

Keywords: Climate change; wheat productivity; farmers' livelihoods; climate-smart agriculture; General Linear Model; Binary Logistic Regression; Punjab, Pakistan.

The Impact of 2025 Flood on Livelihood of Household in District Chiniot, Punjab, Pakistan

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1. Introduction

Floods are among the most devastating climate-induced disasters, causing widespread damage to livelihoods, infrastructure, agriculture, and household well-being. In 2025, severe flooding in the riverine areas of District Chiniot, Punjab, significantly disrupted economic activities and threatened the resilience of rural communities. Understanding the socioeconomic consequences of such disasters is essential for designing effective recovery and disaster risk reduction strategies. This study assesses the impact of the 2025 flood on household livelihoods in the flood-affected areas of Chiniot District.

2. Objectives

The study aims to evaluate the socioeconomic impacts of the 2025 flood on household livelihoods, including income, employment, food security, assets, health expenditures, debt, and perceptions of government relief, while identifying policy measures to strengthen disaster resilience.

3. Methodology

A descriptive cross-sectional survey was conducted using primary data collected from 220 flood-affected households across the three tehsils of Chiniot, Lalian, and Bhowana. Data were gathered through a structured questionnaire covering socioeconomic characteristics, livelihood losses, relief services, and recovery needs. Statistical analysis was performed using SPSS, including descriptive statistics and one-sample t-tests with a neutral Likert scale value of 3.

4. Results

The findings indicate that 85.5% of respondents were directly affected by the flood, while 35.0% temporarily migrated due to severe damage to homes and livelihoods. Average monthly household income declined significantly from PKR 47,500 before the flood to PKR 33,068 after the disaster, representing an average loss of PKR 14,431.82 ($p < 0.001$). The flood also increased household debt, reduced food security, disrupted employment opportunities, raised health expenditures, and caused substantial losses to crops, livestock, and productive assets. Many respondents expressed dissatisfaction with the effectiveness and transparency of government relief efforts.

5. Conclusion & Recommendations

The 2025 flood severely undermined household livelihoods and increased the socioeconomic vulnerability of rural communities in Chiniot. Strengthening early warning systems, improving transparent relief distribution, expanding cash-based assistance, providing agricultural recovery support, and implementing livelihood rehabilitation and climate-resilient disaster management programs are essential to enhance community resilience and sustainable recovery.

Keywords: Flood; household livelihoods; disaster resilience; food security; Chiniot; Punjab; Pakistan.

Biorational Suppression of the Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis* Guénée) Through Entomopathogenic Nematodes: A Sustainable Alternative for Resilient Vegetable Production

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1. Introduction

Brinjal (*Solanum melongena* L.) is an important vegetable crop with high nutritional value; however, its productivity is severely constrained by the brinjal shoot and fruit borer (*Leucinodes orbonalis* Guénée), one of the most destructive insect pests. Larval feeding inside shoots and fruits can cause yield losses of up to 80%, while extensive reliance on chemical insecticides has led to resistance development, pesticide residues, and environmental concerns. Biological control using entomopathogenic nematodes offers a promising, environmentally friendly alternative for sustainable pest management and climate-resilient vegetable production.

2. Objectives

The study aimed to evaluate the efficacy of two entomopathogenic nematode species, *Steinernema carpocapsae* and *Heterorhabditis indica*, against third- and fourth-instar larvae of *L. orbonalis* and determine the effects of nematode concentration and exposure duration on larval mortality.

3. Methodology

Laboratory bioassays were conducted using a completely randomized design with three replications. Freshly collected larvae were exposed to different concentrations of infective juveniles, with the highest treatment (T4) containing 250 infective juveniles, alongside an untreated control. Larval mortality was recorded after 24, 48, 72, and 96 hours. Data were analyzed using analysis of variance (ANOVA), and treatment means were separated using Tukey's Honestly Significant Difference (HSD) test at the 5% significance level.

4. Results

Both entomopathogenic nematode species caused significant mortality across all concentrations and exposure periods. Mortality increased with higher nematode concentrations and longer exposure durations. At 96 hours, treatment T4 produced the highest mortality, reaching 96.67% with *S. carpocapsae* and 95.33% with *H. indica* in third-instar larvae, while fourth-instar mortality reached 86.67% and 89.33%, respectively. Younger larvae were slightly more susceptible, although both nematode species exhibited comparable effectiveness at higher concentrations.

5. Conclusion & Recommendations

Steinernema carpocapsae and *Heterorhabditis indica* demonstrated excellent potential as biological control agents against *L. orbonalis*. Their integration into Integrated Pest Management (IPM) programs can reduce dependence on chemical insecticides, improve environmental sustainability, and enhance resilient brinjal production. Field validation under diverse agroecological conditions is recommended before large-scale adoption.

Keywords: *Leucinodes orbonalis*; entomopathogenic nematodes; *Steinernema carpocapsae*; *Heterorhabditis indica*; biological control; integrated pest management.

Reconciling Oil Palm Expansion with Food Security: Safeguarding the Future of Agricultural Land through Sustainable Landscape Management in Indonesia

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1. Introduction

Indonesia, the world's largest palm oil producer, faces growing concerns over agricultural land conversion, food security, and environmental sustainability. This study explores sustainable landscape management strategies that balance palm oil production with food security, biodiversity conservation, and blue economy initiatives, supporting responsible land use and long-term economic and environmental resilience.

2. Objectives

The study aims to assess the impacts of oil palm expansion on agricultural land availability and food security in Indonesia and propose an integrated landscape management model that supports sustainable palm oil production, agricultural resilience, biodiversity conservation, and blue economy development.

3. Methodology

A qualitative policy analysis synthesized literature, government statistics, satellite-based land-use data, and international reports (2010–2025). Comparative analysis assessed oil palm expansion, agricultural land conversion, and food production. A Food–Palm Oil Integrated Landscape model was developed integrating sustainable land management, spatial planning, precision agriculture, GIS, remote sensing, AI, and seaweed farming.

4. Results

The findings indicate that continued oil palm expansion without effective spatial planning threatens productive agricultural land and national food security. Conversely, sustainable intensification and productivity improvements can increase palm oil production without further land conversion. The proposed integrated landscape model combines protected agricultural land, productive oil palm plantations, conservation areas, agroforestry systems, ecological corridors, and coastal seaweed cultivation while utilizing GIS, remote sensing, and AI to strengthen land-use monitoring and evidence-based decision-making.

5. Conclusion & Recommendations

Indonesia can balance palm oil development and food security through sustainable intensification, agricultural land protection, blue economy initiatives, integrated landscape management, and digital monitoring for resilient, sustainable food systems.

Keywords: Oil palm expansion; food security; agricultural land; sustainable landscape management; land-use change; blue economy; seaweed cultivation; Indonesia.

The Climate Adaptation Paradox: When the Farmers Most Affected by Climate Change Are Least Prepared to Adapt

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1. Introduction

Climate change is intensifying heat stress, droughts, floods, water scarcity, and crop losses, posing severe threats to smallholder farmers in developing countries. Although climate-smart agriculture (CSA) offers practical solutions to improve resilience, adoption remains uneven. A major paradox is that farmers experiencing the highest climate risks are often the least capable of adopting adaptation measures due to financial, institutional, and knowledge constraints. Understanding the relationship between climate vulnerability and adaptive capacity is essential for designing equitable and effective adaptation policies. This study investigates the climate adaptation paradox among smallholder farmers in climate-vulnerable regions of Pakistan.

2. Objectives

The study aims to assess climate vulnerability and adaptive capacity among smallholder farmers, identify socioeconomic, institutional, and behavioral barriers to CSA adoption, and examine how these factors influence farmers' willingness to adopt climate-smart practices.

3. Methodology

Primary data were collected through a structured survey of approximately 200–250 smallholder farmers in climate-vulnerable agricultural regions of Pakistan. Information was gathered on climate exposure, adaptive capacity, and CSA readiness. A Climate Vulnerability Index and an Adaptation Capacity Index were developed, while logistic regression and Structural Equation Modeling (SEM) were employed to examine the relationships between vulnerability, adaptive capacity, and farmers' adaptation decisions.

4. Results

The findings indicate that greater climate vulnerability does not necessarily translate into higher adoption of climate-smart agriculture. Farmers facing the greatest climate risks often possess limited financial resources, inadequate access to credit, extension services, climate information, and digital technologies, which significantly constrain their adaptive capacity. Economic limitations, weak institutional support, and behavioral factors collectively create a substantial "last-mile adaptation gap" between climate policy initiatives and on-farm implementation.

5. Conclusion & Recommendations

Climate adaptation policies should move beyond promoting climate-smart technologies alone and address the underlying socioeconomic and institutional barriers that limit adoption. Expanding access to credit, extension services, climate information, digital technologies, and targeted support for vulnerable farmers will strengthen adaptive capacity, reduce adaptation inequality, and enhance the resilience of Pakistan's agricultural sector under a changing climate.

Keywords: Climate adaptation paradox; climate-smart agriculture; adaptive capacity; smallholder farmers; climate vulnerability; adaptation gap.

The Impact of Climate Shocks on Macroeconomic Stability: Monetary Policy and Inflation Risks for Central Banks

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1. Introduction

Climate change is increasingly recognized as a systemic macroeconomic risk because droughts, floods, heatwaves, wildfires, and other extreme events disrupt production, supply chains, food and energy markets, and labor productivity. These disruptions can generate supply-side inflation, weaken output, increase fiscal pressures, and complicate central banks' efforts to maintain price and financial stability. Classical, Keynesian, and contemporary climate-economics perspectives indicate that climate shocks have evolved from environmental concerns into central macroeconomic and financial-policy challenges. This study examines these transmission mechanisms with particular attention to monetary policy and inflation risks, while considering the structural characteristics of Azerbaijan.

2. Objectives:

The study aims to identify the principal channels through which climate shocks affect macroeconomic stability and inflation; assess the challenges they create for conventional monetary policy; examine policy responses to climate-induced disruptions; and formulate recommendations for strengthening the resilience of Azerbaijan's macroeconomic and financial systems.

3. Methodology:

The study employs a qualitative analytical approach based on theoretical perspectives, comparative assessment of recent international climate shocks, and analysis of monetary, fiscal, and financial policy responses. Evidence from the 2021–2022 heatwaves in Europe and China, the 2022 floods in Pakistan, and the 2023 wildfires in Canada and Mediterranean countries is used to identify common transmission channels. The analysis considers effects on agricultural production, energy supply, transportation, investment, consumption, public expenditure, and inflation. Relevant approaches associated with Malthus, Keynes, Nordhaus, Stern, and Weitzman are integrated to interpret climate-related macroeconomic risks.

4. Results:

The evidence indicates that climate shocks primarily operate through supply-side channels. Reduced agricultural output raises food prices, energy disruptions increase production costs, and damaged transport infrastructure increases logistics expenses. These pressures can weaken economic activity while simultaneously increasing inflation, creating a difficult policy trade-off for central banks. The European and Chinese heatwaves demonstrated how energy shortages and reduced industrial and agricultural production can affect monetary conditions. Pakistan's 2022 floods showed that food, energy, and infrastructure disruptions can sustain inflation despite monetary tightening. The Canadian and Mediterranean wildfires further demonstrated the fiscal and financial consequences of climate disasters through emergency spending, insurance losses, tourism disruptions, and reconstruction costs. International institutions increasingly recommend climate-sensitive inflation forecasting, climate stress testing, macroprudential regulation, green finance, and resilient infrastructure investment.

Theoretical interpretation further suggests that climate shocks differ from conventional demand shocks. Malthus emphasized resource scarcity and food insecurity, Keynes highlighted the need for

active government intervention when supply disruptions destabilize economic activity, while modern climate economics treats climate change as a source of systemic uncertainty and potentially persistent macroeconomic losses. Accordingly, central banks face a dilemma: tightening monetary conditions may contain second-round inflation expectations but can weaken investment and recovery after disasters, whereas excessive accommodation may prolong inflation. The appropriate response therefore depends on shock persistence, inflation expectations, fiscal capacity, exchange-rate conditions, and the credibility of monetary institutions. For Azerbaijan, where energy production and external revenues remain important to macroeconomic performance, climate risks may interact with commodity-price volatility, water scarcity, agricultural losses, and infrastructure vulnerability. Integrating these interactions into scenario analysis and policy planning is therefore essential. Early-warning systems, disaster-risk financing, and reliable climate data should also be strengthened to improve timely policy responses and reduce fiscal and financial losses following extreme events substantially.

5. Conclusion and Policy Recommendations:

Climate shocks should be incorporated systematically into macroeconomic and monetary-policy frameworks. Central banks should strengthen climate-related risk assessment, integrate physical climate risks into inflation forecasting and financial surveillance, and improve stress-testing frameworks. However, monetary policy alone cannot resolve predominantly supply-driven climate inflation. Effective responses require coordinated monetary and fiscal policies, targeted social protection, emergency preparedness, climate-resilient infrastructure, sustainable agricultural investment, and expanded green finance. For Azerbaijan, strengthening diversification, improving energy and water resilience, developing climate-sensitive financial regulation, and enhancing coordination among the Central Bank, government, and financial institutions can reduce vulnerability to climate shocks. Such an integrated framework can help anchor inflation expectations, preserve financial stability, and support sustainable long-term economic growth.

Keywords: Climate shocks; Climate change; Monetary policy; Inflation dynamics; Macroeconomic stability; Central banks; Financial stability; Climate risk; Azerbaijan; Green finance.

Determinants of Farmers Awareness and adoption of water-smart practices of Climate-smart Agriculture (CSA) in the Indus Basin System of Pakistan

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1. Introduction

Climate change, water scarcity, groundwater depletion, and inefficient irrigation threaten agricultural sustainability in Pakistan. This study evaluates farmers' awareness and adoption of water-smart Climate-Smart Agriculture practices, including laser land leveling, zero tillage, raised-bed planting, crop rotation, conjunctive water use, drainage management, and stress-tolerant varieties, in the cotton–wheat system of Punjab's LBDC command area.

2. Objectives

The study aims to assess farmers' awareness and adoption of water-smart CSA practices and identify the socioeconomic, institutional, and farm-level factors influencing their adoption in the cotton–wheat cropping system.

3. Methodology

Primary data were collected from 450 farm households in Khanewal District using a structured questionnaire. A binary logistic regression model was employed to examine the determinants of adopting water-smart CSA practices, while marginal effects were estimated to assess the influence of explanatory variables on adoption probability. Model adequacy was evaluated using the Wald chi-square test and pseudo-R² statistics.

4. Results

The findings indicate widespread adoption of water-smart practices, including raised-bed planting, laser land leveling, conjunctive water use, zero tillage, crop rotation, drainage management, and improved climate-resilient crop varieties. Adoption was significantly influenced by farm characteristics, social and economic capital, technical training, access to information, and exposure to climate risks. Farmers identified limited canal water availability, groundwater depletion, recurring droughts, climate change, and increasing soil salinity as the primary drivers of adoption. The adopted practices improved water-use efficiency, crop establishment, yields, input-use efficiency, and farm profitability.

5. Conclusion & Recommendations

Water-smart CSA practices offer an effective pathway for improving agricultural resilience, water productivity, and rural livelihoods in Pakistan. Policymakers should strengthen agricultural extension services, expand farmer training programs, improve access to climate information and financial support, and promote climate-resilient technologies to accelerate the adoption of water-smart practices. Scaling up these interventions will enhance resource-use efficiency, increase farm incomes, and support sustainable agricultural development under changing climatic conditions.

Keywords: Water-smart agriculture; climate-smart agriculture; cotton–wheat cropping system; water-use efficiency; climate resilience; Pakistan.

Economic Mechanism of Environmental Protection Activities in Oil and Gas Production Enterprises and Sustainable Development Prospects

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1. Introduction

The oil and gas industry is strategically important to Azerbaijan's economy and global energy security, but its production activities generate substantial environmental pressures, including atmospheric emissions, soil and water contamination, hazardous waste, and biodiversity degradation. Climate change, rising carbon emissions, and the transition toward a green economy have increased the need for effective environmental management. This study examines the economic mechanism of environmental protection activities in oil and gas production enterprises and evaluates their contribution to environmental safety and sustainable development.

2. Objectives

The study aims to identify major environmental pollution sources in oil and gas production, examine environmental monitoring and control mechanisms, assess economic instruments for environmental management, and explore opportunities for applying circular economy principles. It also compares Azerbaijan's environmental management practices with international experience, particularly Norway, and evaluates measures implemented by the State Oil Company of the Azerbaijan Republic (SOCAR).

3. Methodology

The study employs a qualitative and comparative analytical approach based on a review of environmental management practices, sectoral measures, and relevant international experience. Major pollution sources, including oil wells, flare systems, pipelines, technical reservoirs, compressor stations, and waste storage facilities, are assessed according to their environmental effects. Environmental monitoring mechanisms covering atmospheric emissions, soil and water quality, pipeline conditions, corrosion, groundwater, and abandoned wells are examined. The study also evaluates circular economy opportunities, including industrial waste recycling, formation-water treatment and reuse, associated-gas utilization, oil-sludge management, and energy-efficiency improvements. Azerbaijan's practices are comparatively assessed against Norway's carbon pricing, emission-control, green-investment, and zero-flaring approaches.

4. Results

The analysis indicates that oil wells, flare systems, pipelines, waste facilities, and compressor stations are major contributors to environmental degradation through methane, carbon dioxide, nitrogen oxides, hydrogen sulfide, oil leakage, and hazardous waste. Environmental monitoring supported by sensors, automated systems, laboratory testing, and digital technologies can improve real-time risk detection and strengthen preventive management. Circular economy practices can simultaneously reduce ecological pressures and improve enterprise efficiency by recovering materials, reusing water, utilizing associated gas, managing oil sludge, and reducing energy consumption. International comparison shows that Norway has more developed carbon taxation, flare reduction, environmental monitoring, and green investment mechanisms. In Azerbaijan, SOCAR has advanced environmental protection through land reclamation, wastewater treatment, flare-gas reduction, environmental monitoring, and energy-efficiency initiatives. These measures generate environmental benefits while potentially reducing operating losses, treatment expenses, energy costs, and land-rehabilitation

requirements. However, carbon pricing, emissions trading, circular economy applications, and dedicated green-finance mechanisms remain areas requiring further development.

Significance: The economic dimension of environmental protection matters because environmental damage creates costs for enterprises and society. Pollution can increase remediation expenditure, reduce land productivity, damage water resources, raise health-related costs, and create regulatory liabilities. Conversely, preventive investments can lower resource consumption, improve operational reliability, and create opportunities for recovering materials and energy from waste. Environmental expenditure should therefore be evaluated not simply as a cost, but as an investment capable of generating economic returns and reducing risks. This perspective supports a shift from remediation toward preventive environmental management and sustainability.

5. Conclusion and Recommendations

Environmental protection in oil and gas enterprises should be treated as both an ecological responsibility and an economic investment in long-term sustainability. An effective economic mechanism should combine regulatory requirements with financial incentives that encourage enterprises to prevent pollution, improve resource efficiency, and adopt cleaner technologies. Azerbaijan can strengthen this mechanism by expanding digital environmental monitoring, introducing stronger carbon-pricing instruments, supporting green investments, improving waste and wastewater recovery, reducing routine flaring, and promoting circular production systems. Greater use of environmental funds, public-private partnerships, and international technological cooperation could further accelerate the transition toward sustainable oil and gas production. Integrating environmental costs into investment and production decisions would also improve accountability and encourage enterprises to consider long-term ecological and economic benefits. Such measures can reduce environmental risks, enhance resource productivity, and strengthen the resilience and competitiveness of Azerbaijan's oil and gas sector while supporting broader sustainable development objectives.

Keywords: Oil and gas industry, environmental safety, environmental protection, circular economy, environmental monitoring, green investment, sustainable development.

Combining Ability Analysis for Leaf Rust Resistance and Yield Related Traits in Bread Wheat Genotypes

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1. Introduction

Leaf rust, caused by *Puccinia triticina*, is one of the most destructive diseases affecting bread wheat production worldwide, resulting in substantial yield and quality losses. Developing high-yielding cultivars with durable leaf rust resistance is a sustainable and cost-effective strategy for disease management. Combining ability analysis provides valuable information on additive and non-additive genetic effects, enabling breeders to identify superior parental lines and promising hybrid combinations. This study evaluates the combining ability of bread wheat genotypes for leaf rust resistance and important yield-related traits to support wheat improvement programs.

2. Objectives

The study aimed to estimate general and specific combining ability for leaf rust resistance and yield-related traits, identify superior parental genotypes and cross combinations, and provide breeding recommendations for developing high-yielding, disease-resistant wheat cultivars.

3. Methodology

Bread wheat genotypes were crossed using an appropriate mating design and evaluated under field conditions. Data were recorded on leaf rust resistance and major agronomic traits, including plant height, spike characteristics, grain yield, and yield components. Analysis of variance and combining ability analyses were performed to estimate general combining ability (GCA) and specific combining ability (SCA) effects and determine the relative contributions of additive and non-additive gene actions.

4. Results

Significant genetic variation was observed among the evaluated genotypes for leaf rust resistance and yield-related traits. Both GCA and SCA effects significantly influenced trait inheritance, indicating the importance of additive and non-additive gene actions. Several parental lines exhibited superior GCA effects for disease resistance and grain yield, while selected cross combinations demonstrated outstanding SCA effects, reflecting strong hybrid performance and substantial breeding potential for developing improved wheat cultivars.

5. Conclusion & Recommendations

Combining ability analysis effectively identified superior wheat parents and cross combinations for leaf rust resistance and yield improvement. Wheat breeding programs should utilize parents with high GCA and hybrids with superior SCA to accelerate the development of high-yielding, leaf rust-resistant cultivars for sustainable wheat production.

Keywords: Bread wheat; leaf rust resistance; combining ability; general combining ability; specific combining ability; grain yield; wheat breeding.

Genetic Characterization and Nanotechnology-Mediated Viral Management in Mungbean (*Vigna radiata* L.).

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1. Introduction

Mungbean (*Vigna radiata* L.) is an important short-duration legume that contributes to food security, soil fertility, and sustainable cropping systems through biological nitrogen fixation. However, its productivity is severely constrained by Mungbean Yellow Mosaic Virus (MYMV), a whitefly-transmitted disease capable of causing substantial yield losses. Conventional chemical control has shown limited effectiveness and poses environmental concerns. Integrating genetic improvement with nanotechnology offers a promising, sustainable strategy for enhancing disease resistance and crop productivity.

2. Objectives

The study aimed to evaluate genetic diversity among mungbean genotypes for yield-related traits and assess the antiviral efficacy of silver nanoparticles (AgNPs) for sustainable management of MYMV.

3. Methodology

Fifteen mungbean genotypes were evaluated using a randomized complete block design with three replications during the Kharif season at the University of Agriculture, Faisalabad. Agronomic traits, including emergence, pods per plant, pod length, seeds per pod, and yield per plant, were recorded. Silver nanoparticles were synthesized through chemical reduction, characterized using X-ray diffraction (XRD) and Zeta potential analysis, and applied as foliar sprays at six concentrations (50–300 mg L⁻¹) to MYMV-infected plants under greenhouse conditions. Statistical analyses included analysis of variance, correlation, and principal component analysis.

4. Results

Highly significant genetic variation was observed among genotypes for all measured traits. Genotype NM-2021 produced the highest yield per plant (8.87 g) and pods per plant (24.7). Principal component analysis identified pods per plant, seeds per pod, and yield as major contributors to genetic variability. XRD confirmed crystalline AgNPs (20–30 nm), while the highest concentration (300 mg L⁻¹) reduced MYMV severity to 5.55% and disease incidence to 22.2%, demonstrating superior antiviral effectiveness.

5. Conclusion & Recommendations

The combined use of elite mungbean genotypes and silver nanoparticles offers an effective and environmentally sustainable strategy for MYMV management. Future breeding programs should exploit superior genotypes such as NM-2021 while integrating nanotechnology-based disease management to enhance climate resilience, reduce pesticide dependence, and improve sustainable mungbean production.

Keywords: Mungbean; Mungbean Yellow Mosaic Virus; genetic diversity; silver nanoparticles; antiviral efficacy; climate-smart agriculture.

Evaluation of Exotic Chickpea (*Cicer arietinum* L.) Germplasm under Irrigated Conditions

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1. Introduction

Chickpea (*Cicer arietinum* L.) is one of the most important leguminous crops globally due to its high nutritional value and contribution to sustainable agriculture. However, chickpea production has declined drastically in recent years because of frequent drought conditions and limited water availability. In addition, the narrow genetic base of existing cultivars poses a significant barrier to further genetic improvement. Therefore, the utilization of exotic and diverse germplasm is essential to broaden genetic diversity and improve crop resilience.

2. Objectives

The study aimed to evaluate the performance of exotic chickpea genotypes under irrigated conditions for morphological, yield, and nutritional traits and to identify promising genotypes with potential utility in future chickpea breeding programs.

3. Methodology

A total of 11 exotic genotypes (3 Kabuli and 8 Desi) sourced from Australia were evaluated alongside two local checks, Noor-2022 (Kabuli) and Bittal-2021 (Desi). The experiment was conducted for two consecutive seasons at the Department of Plant Breeding and Genetics, University of Agriculture, Faisalabad. During Season I (2023–24), seed multiplication and preliminary evaluation were performed without replication. During Season II (2024–25), the genotypes were evaluated using a randomized complete block design (RCBD) with three replications. The morphological and yield traits recorded included emergence percentage, days to 50% flowering, days to pod development, plant height, number of tillers per plant, number of pods per plant, pod length, pod diameter, number of seeds per pod, plant yield, and 100-seed weight. Biochemical analysis included crude protein, crude fat, crude fiber, ash content, and total phenolic content (TPC).

4. Results

Significant genotypic variation was observed for all studied traits. Among the Desi types, Bittal-2021 exhibited superior plant yield, whereas Noor-2022 performed better among Kabuli types for pod number, 100-seed weight, and total phenolic content. Among the exotic genotypes, PBA-Drummond and PBA-Captain performed well for morphological traits, while Kalkee and Kyabra showed potential for nutritional traits. Although the local checks generally outperformed the exotic genotypes in overall yield and adaptability, several exotic lines demonstrated valuable morphological and nutritional characteristics.

5. Conclusion & Recommendations

The findings demonstrated considerable genetic variability among the evaluated chickpea genotypes, with several exotic lines showing promising morphological and nutritional attributes. These genotypes may serve as valuable sources of genetic diversity for future chickpea improvement programs. Since the exotic genotypes were still in the adaptability evaluation phase, further studies under multi-location and stress conditions are recommended to validate their performance, stability, and adaptability before their utilization in breeding programs.

Keywords: Chickpea, Irrigated Conditions, Exotic Germplasm, Genetic variability, Adaptability

Evaluation of Chickpea (*Cicer arietinum* L.) Germplasm for Herbicide Tolerance under Pre-Emergence Herbicide Application

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1. Introduction

Chickpea (*Cicer arietinum* L.) is an important grain legume and a major source of dietary protein worldwide. However, severe weed infestation during early crop establishment significantly reduces plant growth and yield. Although pre-emergence herbicides effectively suppress weeds, many chickpea genotypes exhibit sensitivity to herbicide application, limiting their widespread adoption. Identifying herbicide-tolerant germplasm is therefore essential for integrating effective weed management with chickpea improvement and sustainable crop production.

2. Objectives

The study aimed to evaluate the herbicide tolerance of diverse chickpea germplasm under pre-emergence application of S-metolachlor, identify tolerant genotypes, and determine key agronomic traits associated with improved performance under herbicide stress.

3. Methodology

Forty chickpea genotypes, comprising 20 Desi and 20 Kabuli types, were evaluated under field conditions using a randomized complete block design with three replications. S-metolachlor was applied as a pre-emergence herbicide. Data were collected on emergence percentage, survival rate, phenological characteristics, plant height, pods per plant, plant yield, and 100-seed weight. Analysis of variance, correlation analysis, and principal component analysis were performed to assess genetic variability, trait relationships, and genotype performance under herbicide stress.

4. Results

Significant genetic variation was observed for emergence, survival, plant height, pods per plant, grain yield, and 100-seed weight. Correlation analysis identified pods per plant and related yield components as the strongest contributors to grain yield, while principal component analysis explained more than 70% of the total phenotypic variation. Among the Desi genotypes, G183, G238, and G127 exhibited the highest herbicide tolerance and agronomic performance, whereas G532, G561, and G725 were the most promising Kabuli genotypes under S-metolachlor application.

5. Conclusion & Recommendations

The identified tolerant genotypes provide valuable genetic resources for developing herbicide-tolerant chickpea cultivars. Future breeding programs should incorporate these genotypes and validate their performance across diverse environments to support integrated weed management and sustainable chickpea production.

Keywords: Chickpea; S-metolachlor; pre-emergence herbicide; herbicide tolerance; genetic variability; weed management.

Characterization of Faba Bean (*Vicia faba* L.) Genotypes for Yield, Adaptability, and Soil Fertility Enhancement in Pakistan's Rabi Cropping System

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1. Introduction

Faba bean (*Vicia faba* L.) is a nutrient-rich cool-season grain legume with considerable potential to diversify Pakistan's rabi cropping system. Besides providing high-quality protein, it improves soil fertility through biological nitrogen fixation, thereby enhancing the sustainability of cereal-based production systems. Despite these advantages, its cultivation remains limited due to the lack of well-adapted, high-yielding cultivars. Evaluating diverse germplasm is essential for broadening the genetic base and identifying elite genotypes suitable for crop improvement and sustainable agriculture.

2. Objectives

The study aimed to assess the genetic diversity, yield potential, and adaptability of diverse faba bean genotypes and identify superior breeding materials for cultivar development and sustainable pulse production in Pakistan.

3. Methodology

A total of 300 faba bean genotypes, along with two standard check varieties, were evaluated during the 2025–26 rabi season at the University of Agriculture, Faisalabad, using an augmented block design. Data were recorded for ten quantitative and four qualitative traits. Statistical analyses included analysis of variance, correlation analysis, principal component analysis, and cluster analysis to determine genetic variability, trait associations, and genetic divergence among the evaluated germplasm.

4. Results

Highly significant genetic variation ($p \leq 0.01$) was observed for plant height, pod length, plant yield, and 100-seed weight. Plant yield ranged from 1.16 to 62.80 g, with a mean of 19.77 g. Genotypes P287, P163, P273, P133, and P127 exhibited superior yield performance. Pods per plant showed the strongest positive association with grain yield, highlighting its importance as a selection criterion. Cluster analysis grouped the germplasm into five distinct genetic clusters, demonstrating substantial diversity for future breeding.

5. Conclusion & Recommendations

The identified elite genotypes provide valuable genetic resources for developing high-yielding, locally adapted faba bean cultivars. Future breeding programs should exploit the observed genetic diversity and validate promising lines across multiple environments to enhance crop diversification, improve soil fertility, strengthen food and nutritional security, and promote sustainable rabi farming systems in Pakistan.

Keywords: Faba bean; genetic diversity; yield improvement; crop diversification; sustainable agriculture; nitrogen fixation.

Gamma Irradiation-Induced Genetic Variability and Yield Potential in Mung Bean (*Vigna radiata* L.) Cultivars

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1. Introduction

Mung bean (*Vigna radiata* L.) is an important grain legume valued for its high protein content, nutritional quality, and biological nitrogen fixation. However, its genetic improvement is constrained by a narrow genetic base, limiting progress in developing high-yielding and climate-resilient cultivars. Mutation breeding using gamma irradiation is an effective approach for generating novel genetic variation and expanding the breeding pool. This study evaluated gamma irradiation-induced variability and identified promising mutant lines for yield improvement in mung bean.

2. Objectives

The study aimed to induce genetic variability through gamma irradiation, evaluate the agronomic performance of mutant populations, and identify superior genotypes and key yield-contributing traits for future mung bean breeding programs.

3. Methodology

Fifteen mung bean cultivars were exposed to different doses of gamma irradiation, and the treated (M₀) seeds were evaluated under field conditions using a randomized complete block design at the University of Agriculture, Faisalabad. Data were recorded on emergence percentage, plant height, plant biomass, pods per plant, pod length, seeds per pod, yield per plant, harvest index, and 100-seed weight. Statistical analyses included analysis of variance, least significant difference tests, and correlation analysis to assess genetic variability and trait associations.

4. Results

Significant genetic variation was observed among irradiated mutants and control plants for most evaluated traits. Genotypes NM-98 and NM-19-19 demonstrated superior performance across different irradiation treatments, with NM-98 exhibiting the highest emergence percentage at 150 Gy. Correlation analysis revealed significant positive associations between yield per plant and emergence percentage, plant height, plant biomass, pods per plant, pod length, and seeds per pod, indicating their importance as selection criteria for yield improvement.

5. Conclusion & Recommendations

Gamma irradiation effectively generated useful genetic variability in mung bean and identified promising mutant lines for breeding. Future breeding programs should exploit superior mutants such as NM-98 and NM-19-19, validate their performance across diverse environments, and integrate them into cultivar development programs to enhance productivity, climate resilience, and sustainable mung bean production.

Keywords: *Vigna radiata*; gamma irradiation; mutation breeding; genetic variability; yield improvement; climate resilience.

Groundwater Irrigation, Water Use Efficiency, and Agricultural Productivity in Water-Scarce Regions: Evidence from Balochistan, Pakistan

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1. Introduction

Groundwater has become the primary source of irrigation in Balochistan, Pakistan, where recurrent droughts, limited surface water resources, and increasing water scarcity have intensified dependence on rapidly depleting aquifers. Although groundwater irrigation supports agricultural production and rural livelihoods, excessive extraction threatens long-term water security and sustainable farming. Evaluating groundwater use efficiency and its economic implications is essential for developing resilient water management strategies in water-scarce regions.

2. Objectives

This study assessed groundwater irrigation efficiency, crop productivity, and the economic performance of groundwater-dependent farming systems in District Quetta, Balochistan. It also examined the influence of groundwater extraction costs on agricultural productivity and identified policy measures for sustainable groundwater management.

3. Methodology

Primary data were collected from 100 randomly selected farmers across five villages using a structured questionnaire. Crop water productivity, water use efficiency (WUE), and benefit-cost ratios (BCR) were estimated for major crops. A double-log regression model was employed to analyze the effects of groundwater use costs on the gross value product of agricultural production.

4. Results

Agriculture alone was insufficient to meet average household expenditures, making livestock and non-farm income important livelihood sources. All major crops were economically profitable; however, profitability depended heavily on groundwater irrigation. Wheat recorded the highest water productivity (1.19 kg/m³), whereas maize and tomato required substantially higher irrigation volumes. Regression analysis revealed that rising groundwater extraction costs significantly reduced the gross value product of wheat and maize, highlighting farmers' vulnerability to declining groundwater availability and increasing pumping expenses.

5. Conclusion & Recommendations

Sustainable groundwater management is essential for maintaining agricultural productivity and livelihood security in Balochistan. Policymakers should promote water-efficient irrigation technologies, strengthen groundwater governance, improve farmers' access to quality agricultural inputs, and expand capacity-building programs to enhance water productivity, climate resilience, and long-term food security.

Keywords: Groundwater irrigation; Water use efficiency; Agricultural productivity; Livelihoods; Balochistan; Pakistan.

Green Finance and Carbon Intensity: A Moderated Mediation Analysis of Renewable Energy Adoption, Environmental R&D, and Financial Inclusion

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1. Introduction

Climate change and increasing carbon emissions have heightened the need for sustainable financial systems that support the transition to low-carbon economies. Green finance has emerged as a key policy instrument for promoting environmentally responsible investments and reducing carbon intensity. However, limited empirical evidence exists on the mechanisms through which green finance influences carbon emissions, particularly the mediating roles of renewable energy adoption and environmental research and development (R&D), and the moderating effect of financial inclusion. This study investigates these interrelationships to provide evidence-based insights for sustainable development policies in OECD countries.

2. Objectives

This study examines the direct and indirect effects of green finance on carbon intensity in OECD economies. Specifically, it evaluates the mediating roles of renewable energy adoption and environmental R&D intensity, while assessing whether financial inclusion strengthens these mediation pathways.

3. Methodology

An unbalanced panel dataset of OECD countries covering the period 2003–2022 was analyzed using advanced panel econometric techniques to address cross-country heterogeneity and potential endogeneity. A moderated mediation framework was employed to estimate the direct impact of green finance on carbon intensity, the mediating effects of renewable energy adoption and environmental R&D, and the moderating role of financial inclusion.

4. Results

The findings reveal that green finance significantly reduces carbon intensity through both direct and indirect pathways. Renewable energy adoption and environmental R&D intensity serve as significant mediators, explaining how green finance contributes to decarbonization. Moreover, financial inclusion positively moderates these relationships by enhancing access to financial resources, thereby strengthening investments in renewable energy and environmental innovation. The integrated framework demonstrates that inclusive financial systems amplify the effectiveness of green finance in reducing carbon emissions.

5. Conclusion & Recommendations

Green finance is an effective instrument for reducing carbon intensity when supported by renewable energy development, environmental innovation, and inclusive financial systems. Policymakers should integrate green finance policies with financial inclusion initiatives, expand investments in renewable energy technologies, and strengthen environmental R&D to accelerate decarbonization and achieve long-term climate and sustainable development goals across OECD economies.

Keywords: Green finance; Carbon intensity; Renewable energy adoption; Environmental R&D; Financial inclusion.

Methodology for Assessing the Impact of Oil Price Shocks on the Exchange Rate

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1. Introduction

Oil-exporting economies often experience exchange-rate pressures following changes in international oil prices. This study develops a methodological framework for assessing the short- and long-run effects of oil price shocks on exchange rates in Saudi Arabia, Iraq, Kuwait, the United Arab Emirates (UAE), and Azerbaijan. Particular attention is given to the role of oil rents and sovereign oil-fund expenditures as potential shock absorbers that may weaken the transmission of oil price volatility to national currencies.

2. Objectives

The study aims to examine the relationship between world oil prices and nominal exchange rates, identify differences between short- and long-run effects, assess the role of oil rents in exchange-rate dynamics, and determine whether state regulation and sovereign wealth management moderate the transmission of external oil shocks.

3. Methodology

Annual data covering approximately three decades are used for world oil prices, oil rents, and nominal exchange rates. Annual average oil prices in US dollars are obtained from the U.S. Energy Information Administration, while real oil prices are derived using the United States price index. The analysis considers the exchange rates of the Saudi riyal, Iraqi dinar, Kuwaiti dinar, UAE dirham, and Azerbaijani manat. Stationarity is examined using Augmented Dickey–Fuller and Phillips–Perron tests at levels and first differences, while the Zivot–Andrews test is applied to account for structural breaks. Bounds testing is then used to examine cointegration, followed by an Autoregressive Distributed Lag model to estimate short- and long-run relationships. Granger causality tests are employed to assess directional relationships. For Azerbaijan, oil-fund expenditures are additionally considered because the domestic effect of oil revenues depends substantially on the amount actually transferred into the economy. This framework recognizes that exchange rates in the selected countries are influenced by monetary and fiscal authorities and are not determined solely by market forces.

4. Results

The time-series tests indicate that the examined variables are generally non-stationary at levels but become stationary after first differencing, supporting the application of cointegration-based methods. The empirical evidence shows that the Saudi riyal, Iraqi dinar, Kuwaiti dinar, UAE dirham, and Azerbaijani manat exhibit limited short-run sensitivity to world oil prices. In contrast, long-run dependence is evident for the currencies of all five oil-producing countries. This pattern suggests that exchange-rate management, foreign-exchange reserves, monetary interventions, and sovereign oil-revenue management can substantially smooth the immediate effects of oil price fluctuations. The analysis further indicates that oil rents do not significantly influence exchange rates in the short run. However, long-run dependence is observed particularly for Iraq and Kuwait, where oil rents constitute a substantial component of national income. The declining share of oil rents in GDP in Saudi Arabia, the UAE, and Azerbaijan suggests gradual economic diversification, although oil remains strategically important. Real-price calculations also demonstrate that the apparent long-term increase in nominal oil prices partly reflects changes in the purchasing power of the US dollar.

5. Conclusion and Recommendations

The findings demonstrate that oil price shocks do not translate mechanically into immediate exchange-rate movements in the selected economies. State intervention, reserve management, and sovereign wealth funds can act as stabilizing mechanisms and weaken short-run transmission. Nevertheless, persistent oil dependence creates long-run exposure to external price shocks. Policymakers should therefore strengthen fiscal buffers, maintain adequate foreign-exchange reserves, improve sovereign fund management, promote economic diversification, and enhance exchange-rate flexibility where appropriate. For Azerbaijan, coordinating oil-fund expenditures with monetary and exchange-rate policy is particularly important for preserving macroeconomic stability. The proposed methodological framework can support comparative research on resource-dependent economies and improve understanding of the channels through which oil-price shocks affect exchange-rate dynamics. These results also imply that annual oil-price measures should be interpreted cautiously because short-term market volatility may be obscured by averaging. Future studies could employ quarterly or monthly observations, alternative oil benchmarks, nonlinear specifications, and additional indicators of fiscal transfers and reserve adequacy to capture asymmetric shocks and improve the robustness of exchange-rate transmission estimates across policy regimes and periods.

Keywords: Oil Price Shocks, Exchange Rate, Oil Rents, Exchange Rate Volatility, ARDL Model, Cointegration, Granger Causality, Sovereign Wealth Funds, Azerbaijan, Oil-Exporting Countries

Ensuring Investment Attractiveness of Green Projects to Solutions to Global Environmental Problems

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1. Introduction

Global environmental challenges, including climate change, greenhouse gas emissions, resource depletion, pollution, and biodiversity loss, require substantial investment in environmentally sustainable economic activities. Green projects have emerged as an important mechanism for protecting and restoring natural resources while promoting economic development. However, their successful implementation depends largely on their investment attractiveness and the willingness of private and institutional investors to provide long-term financing. In this context, governments increasingly employ economic and administrative incentives, including tax concessions, customs preferences, subsidized credit, favorable tariffs, and other financial mechanisms. Azerbaijan also possesses significant potential for developing green projects, particularly in non-oil processing industries, renewable energy, waste management, resource efficiency, and environmentally sustainable infrastructure.

2. Objectives

This study aims to examine the factors determining the investment attractiveness of green projects and identify effective economic, financial, regulatory, and digital mechanisms for stimulating investor participation. It also considers the role of government support, green finance, public–private partnerships, technological innovation, and international cooperation in accelerating Azerbaijan's transition toward a sustainable and green economy.

3. Methodology

The study employs a qualitative analytical approach based on the synthesis of existing research and conceptual analysis of green investment, sustainable production, environmental protection, green finance, and economic transformation. Particular attention is given to international experiences concerning investment incentives, environmental regulation, green infrastructure, resource recycling, renewable energy, digital technologies, and public–private partnerships. The analysis further considers the opportunities and challenges associated with implementing green projects in Azerbaijan's non-oil processing industries and identifies policy measures capable of improving their investment attractiveness.

4. Results

The analysis indicates that investment attractiveness is a decisive factor in ensuring the successful implementation and long-term sustainability of green projects. Preferential taxation, customs exemptions, concessional financing, favorable tariffs, and other targeted incentives can significantly reduce investment risks and encourage private-sector participation. Green processing projects have considerable potential to transform waste and other renewable resources into environmentally friendly energy and useful products, thereby reducing resource losses and anthropogenic pressure on the environment. Digital transformation further creates opportunities to identify resource and energy inefficiencies rapidly and improve production efficiency. The development of green economic activities can stimulate structural transformation through emerging industries such as waste processing, zero-emission energy production, greenhouse-gas absorption, green urbanism, and post-mining activities.

Green investments can simultaneously support carbon reduction, energy and resource efficiency, biodiversity conservation, employment creation, and productivity growth. In Azerbaijan, the development of green projects in non-oil processing industries can contribute to economic diversification and strengthen the country's alignment with international environmental and sustainable development objectives. However, achieving a comprehensive green transition requires coordinated development across industries, widespread adoption of green technologies, supportive regulatory institutions, and stronger financial mechanisms. Green finance is particularly important because it connects environmental objectives with investment decisions and facilitates the mobilization of resources toward environmentally responsible projects. Public expenditure, policy reforms, regulatory improvements, foreign investment, and public-private partnerships can collectively strengthen the financing environment. Digital platforms can also improve transparency, resource management, project monitoring, and investor access to information.

5. Conclusion & Recommendations

The study concludes that increasing the investment attractiveness of green projects is essential for addressing environmental challenges while supporting sustainable economic growth. Azerbaijan should establish effective investment regulations, expand tax and financial incentives, strengthen green financing mechanisms, and actively attract foreign and private investment. Digital platforms should be integrated into investment and resource-management systems to improve efficiency and transparency. Public-private partnerships should be strengthened for green infrastructure, renewable energy, waste processing, sustainable urban development, and resource-efficient production. Greater international cooperation and exchange of experience are also recommended to accelerate technological innovation and green transformation. Coordinated government policies, private investment, innovative technologies, and environmentally responsible production can create a stronger foundation for sustainable development and contribute to Azerbaijan's transition toward a resilient, resource-efficient, and low-carbon economy.

Keywords: Green Projects, Investment Attractiveness, Green Economy, Green Finance, Sustainable Development, Environmental Protection, Green Investment, Azerbaijan, Digital Transformation.

Genotypic Evaluation of Early Generation Sweet Corn (*Zea mays* subsp. *saccharata*) Inbred Lines under Stage-Specific Water Stress

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1. Introduction

Sweet corn (*Zea mays* subsp. *saccharata*) is a high-value vegetable crop valued for its nutritional quality, sweetness, and processing potential. However, its productivity is highly vulnerable to water stress, particularly during critical growth stages, where yield losses may exceed 60%. Despite its economic significance, limited breeding efforts have focused on developing drought-tolerant sweet corn cultivars. Identifying superior inbred lines with improved performance under stage-specific water stress is essential for enhancing climate resilience and sustainable production.

2. Objectives

This study evaluated the performance of early-generation sweet corn inbred lines under stage-specific water stress and identified superior genotypes and key selection traits for developing drought-tolerant cultivars.

3. Methodology

Field experiments were conducted over two consecutive seasons at the University of Agriculture, Faisalabad. Eight S_2 and twenty-seven S_3 exotic sweet corn inbred lines were evaluated under normal irrigation and water stress imposed at flowering, grain filling, and maturity using a split-plot design with two replications. Morphological and yield-related traits were analyzed using analysis of variance, Tukey's HSD test, correlation, regression, heritability estimates, genetic advance, and principal component analysis (PCA).

4. Results

Genotypes, water stress treatments, and their interactions significantly affected most evaluated traits. WSC-99 and WSC-01 were identified as superior parental lines, while hybrids YSC-811 × WSC-01 and YSC-811 × WSC-99 performed best in the S_2 generation. Among the S_3 lines, PBGSC-345, PBGSC-328, PBGSC-344, PBGSC-333, and PBGSC-337 exhibited superior agronomic and yield performance under water stress. Cob weight, rows per cob, seeds per cob, grain weight, and 100-grain weight showed high heritability and genetic advance, indicating their suitability as reliable selection criteria. PCA explained 91.88% and 82.77% of the total variation in the S_2 and S_3 generations, respectively.

5. Conclusion & Recommendations

The identified superior inbred lines represent valuable genetic resources for breeding climate-resilient and drought-tolerant sweet corn cultivars. Breeding programs should prioritize highly heritable yield traits to accelerate genetic improvement. Developing water-efficient sweet corn varieties will enhance resource use efficiency, reduce irrigation requirements, strengthen climate resilience, and promote sustainable agricultural production.

Keywords: Sweet corn; Inbred lines; Water stress; Drought tolerance; Climate resilience; Genetic variability; Selection criteria.

Renewable Energy, Natural Resource Rents and Sustainable Economic Growth: Evidence from Pakistan

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1. Introduction

The transition to renewable energy is essential for achieving sustainable economic growth, particularly in developing economies characterized by resource dependence and macroeconomic instability. Although Pakistan possesses substantial renewable energy potential, its economy remains heavily reliant on conventional energy sources and natural resource extraction, raising concerns about long-term sustainability. Understanding the contribution of renewable energy and natural resource rents to economic growth is therefore critical for designing effective development policies.

2. Objectives

This study examines the short-run and long-run effects of renewable energy consumption and natural resource rents on Pakistan's economic growth. It also evaluates the roles of foreign direct investment (FDI), inflation, population growth, and gross capital formation in promoting sustainable economic development.

3. Methodology

Annual time-series data covering 1990–2022 were analyzed using the Autoregressive Distributed Lag (ARDL) bounds testing approach. Gross domestic product (GDP) growth was modeled as the dependent variable, while renewable energy consumption, natural resource rents, gross capital formation, inflation, population growth, and FDI were included as explanatory variables. Diagnostic and stability tests were performed to ensure model reliability and robustness.

4. Results

The findings reveal that renewable energy consumption, natural resource rents, and gross capital formation have significant positive long-run effects on economic growth. Conversely, inflation and population growth negatively influence economic performance. The error correction model (ECM) confirms a significant short-run adjustment process, indicating convergence toward long-run equilibrium following short-term economic shocks.

5. Conclusion & Recommendations

Renewable energy plays a pivotal role in supporting sustainable long-term economic growth in Pakistan. However, excessive dependence on natural resource rents may reinforce resource dependence and increase macroeconomic vulnerabilities. Policymakers should expand investment in renewable energy, strengthen capital formation, attract productive FDI, and maintain macroeconomic stability through effective inflation control. These measures will promote inclusive, resilient, and environmentally sustainable economic growth.

Keywords: Renewable energy; Natural resource rents; Economic growth; Capital formation; ARDL; Pakistan

Enhancing Farm Income through Water-Efficient Crop Diversification: Evidence from Faisalabad, Pakistan

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1. Introduction:

Pakistan's agriculture faces increasing water scarcity and groundwater depletion, particularly in Punjab's irrigated plains. Dominance of water-intensive crops such as rice and sugarcane, combined with limited crop diversification, constrains water productivity and farm profitability. This study examines whether water-efficient crop diversification can improve farm income while conserving scarce water resources in Faisalabad.

2. Objectives:

The study aims to assess the relationship between crop diversification, water productivity, and farm income; identify water-efficient cropping systems; and develop crop combinations that balance economic returns with water conservation.

3. Methodology:

Primary data were collected from 150 farm households in Faisalabad covering crop yields, irrigation practices, production costs, revenues, and water consumption. Water productivity was measured using biophysical (kg/m^3) and economic (Rs/m^3) indicators. Farm budgeting, Crop Diversification Index (CDI), and econometric models were employed to evaluate profitability, water-use efficiency, and determinants of diversification.

4. Results:

Substantial differences were observed in water productivity and profitability among cropping systems. Sugarcane generated the highest income and water productivity but consumed the greatest volume of water, whereas rice demonstrated the lowest water-use efficiency. Mustard emerged as the most water-saving crop, while wheat and maize showed relatively balanced performance. The average CDI was 0.45, indicating moderate diversification. Econometric results showed that diversification had a positive and highly significant effect on farm income and water productivity. Farmer organization membership improved both outcomes, while farming experience and credit access significantly promoted diversification.

5. Conclusion & Recommendations:

Water-efficient crop diversification offers a viable pathway for improving farm income and conserving water in Faisalabad. Policies should promote region-specific crop combinations, water-efficient alternatives, affordable credit, farmer organizations, improved irrigation infrastructure, and market support. Integrating kg/m^3 and Rs/m^3 indicators into agricultural planning and subsidy policies can further encourage sustainable water use.

Keywords: Crop Diversification; Water Productivity; Farm Income; Irrigation Efficiency; Sustainable Agriculture

The Effects of International Tariffs, FDI, and Tourism on Transport CO₂ Emissions: Evidence from SCO Countries

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1. Introduction:

The Shanghai Cooperation Organization (SCO) comprises rapidly emerging economies whose trade, investment, tourism, and industrial policies have important implications for transboundary environmental sustainability. This study investigates the effects of international tariffs, foreign direct investment (FDI), tourism, industrialization, and inflation on transport-related CO₂ emissions across SCO countries during 1994–2024. Particular attention is given to the heterogeneous environmental effects of tariff mechanisms.

2. Objectives:

The study examines the short- and long-run effects of tariff regimes, FDI, tourism, industrialization, and inflation on transport CO₂ emissions and identifies policy pathways for reducing emissions while sustaining trade and investment.

3. Methodology:

A unified empirical framework was developed using Principal Component Analysis (PCA), Dynamic Panel Autoregressive Distributed Lag (DPARDL) with Error Correction Mechanism (ECM), and Kernel Regularized Least Squares (KRLS). Panel data covering SCO member countries from 1994 to 2024 were analyzed to examine long-run equilibrium relationships, dynamic effects, persistence, and nonlinear causal patterns.

4. Results:

The findings indicate a long-run equilibrium relationship among FDI, international tariff measures, tourism, and transport CO₂ emissions, with emissions demonstrating substantial persistence. FDI reduces transport CO₂ emissions over time, potentially through cleaner technology transfer, whereas industrialization emerges as the dominant source of emissions. International tariff effects are stronger in the medium and long run but vary across countries in the short run. Tourism responds differently to tariff measures across China, India, and Pakistan, confirming heterogeneous country-specific effects.

5. Conclusion & Recommendations:

Tariff mechanisms influence transport emissions through multiple channels rather than producing uniform environmental effects. Policymakers should avoid unnecessarily restricting FDI and instead promote environmentally oriented investment, clean-technology transfer, and targeted tariff incentives that support low-carbon development across SCO economies.

Keywords: International Tariffs; Industrial Development; International Tourism; FDI; Transport CO₂ Emissions; SCO Countries

Urbanization and Industrialization in Pakistan: Their Impact on Economic Growth

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1. Introduction:

Urbanization and industrialization are fundamental drivers of structural transformation and economic development. Pakistan is experiencing rapid urban expansion, with more than half of its population projected to reside in urban areas by 2030. However, weaknesses in industrial infrastructure, productivity, investment, and urban planning may constrain the contribution of these processes to economic growth. This study examines the effects of urbanization and industrialization on Pakistan's economic growth while considering other important macroeconomic factors.

2. Objectives:

The study aims to assess the short- and long-run effects of urbanization and industrialization on GDP per capita in Pakistan and examine the roles of inflation, foreign direct investment (FDI), and population growth.

3. Methodology:

Annual data covering 1980–2024 were analyzed using the Autoregressive Distributed Lag (ARDL) model to estimate short- and long-run relationships. The Augmented Dickey-Fuller (ADF) test was employed to examine stationarity, while cointegration analysis assessed long-run equilibrium relationships. An error correction model was used to determine the speed of adjustment toward equilibrium.

4. Results:

The findings indicate that urbanization has a positive and statistically significant effect on GDP per capita, reflecting benefits from labor mobility, market expansion, and infrastructure development. In contrast, industrialization has a negative and significant long-run effect, potentially reflecting low productivity, energy shortages, inadequate investment, and structural inefficiencies. FDI contributes positively to economic growth in the long run, while population growth has a negative but statistically insignificant effect. Inflation shows a statistically significant positive association with GDP per capita.

5. Conclusion & Recommendations:

The study concludes that Pakistan needs efficient and sustainable industrial development alongside planned urbanization, improved infrastructure, increased productive investment, and macroeconomic stability to achieve sustained economic growth.

Keywords: Urbanization, Industrialization, Economic Growth, Inflation, Pakistan]

SECTION II

2. Agri-Food System Transformation and Market Dynamics

9 Abstracts

Safeguarding Maize Food Security from an Invasive Pest: Insecticide Resistance Status of Faisalabad and Sahiwal Populations of Fall Armyworm (*Spodoptera frugiperda*) in Punjab, Pakistan

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1. Introduction

The fall armyworm (*Spodoptera frugiperda*) has emerged as one of the most destructive invasive pests threatening maize production in Pakistan since its introduction in 2019. Intensive and repeated insecticide applications have increased the risk of resistance development, undermining sustainable pest management and food security. Because resistance evolves according to local insecticide use patterns, district-specific resistance monitoring is essential for developing effective integrated pest management (IPM) strategies.

2. Objectives

This study evaluated and compared the insecticide resistance status of *S. frugiperda* populations from Faisalabad and Sahiwal against commonly used insecticides and identified effective products for sustainable resistance management.

3. Methodology

Third-instar larvae collected from Faisalabad and Sahiwal, along with a laboratory-susceptible strain, were evaluated using the leaf-dip bioassay against eleven commercial insecticides at five concentrations. Mortality was recorded after 12, 24, 48, 72, and 168 hours. Corrected mortality data were analyzed using three-factor ANOVA and Tukey's test, while probit analysis was employed to estimate LC₅₀ values and resistance ratios following established classification criteria.

4. Results

Insecticide type, concentration, and strain significantly affected larval mortality. The laboratory strain remained the most susceptible, followed by the Sahiwal and Faisalabad populations. Weekly mortality ranged from approximately 29% for lufenuron alone against the Faisalabad population to 90% for the emamectin benzoate + chlorantraniliprole mixture against the susceptible strain. The highest resistance ratios were observed for the emamectin benzoate + lufenuron formulation, reaching 77.7-fold in Faisalabad and 40.9-fold in Sahiwal, indicating high resistance. In contrast, binary insecticide formulations generally maintained superior efficacy compared with single-active-ingredient products.

5. Conclusion & Recommendations

The findings indicate that fall armyworm resistance in Punjab is emerging and requires immediate management. Restricting repeated use of single-active insecticides, promoting binary formulations with different modes of action, strengthening resistance monitoring, and integrating biological and botanical control measures within IPM programs will enhance sustainable maize protection, delay resistance evolution, and safeguard food security.

Keywords: *Spodoptera frugiperda*; insecticide resistance; maize; resistance ratio; integrated pest management; leaf-dip bioassay.

CPEC and the Transformation of Agricultural Value Chains and Market Linkages in Pakistan

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1. Introduction

The China–Pakistan Economic Corridor (CPEC) is one of the largest infrastructure and regional connectivity initiatives in Pakistan, with significant potential to transform agricultural markets and value chains. By improving transport networks, logistics, and regional trade, CPEC can enhance market access, reduce transaction costs, and strengthen agricultural competitiveness. However, empirical evidence on its contribution to agricultural value chain development and market integration remains limited. This study evaluates the role of CPEC in transforming agricultural value chains, improving market linkages, and identifying institutional constraints affecting agricultural development in Pakistan.

2. Objectives

This study assesses the effects of CPEC-related transport and logistics infrastructure on market access, agricultural output, farmer income, price transmission, and value chain efficiency, while identifying policy and institutional challenges influencing agricultural transformation.

3. Methodology

A mixed-methods approach was employed using secondary data and expert opinions. Secondary information from national and international reports, development databases, and published literature (2013–2025) was synthesized through a systematic mapping review following PRISMA guidelines. In addition, a structured questionnaire was administered to 50 experts from academia, government, and industry. Descriptive statistics and thematic content analysis were used to interpret the findings.

4. Results

The findings indicate that CPEC has substantially improved transportation infrastructure and market connectivity, enhancing market access and strengthening linkages between production and consumption centers. However, gains in logistics efficiency, post-harvest management, and value chain integration remain moderate due to inadequate cold-chain facilities, storage infrastructure, and institutional coordination. Agricultural output and farmer income have improved indirectly, while price transmission efficiency continues to be constrained by market inefficiencies and intermediary dominance. The review further highlights limited attention to smallholder inclusion, institutional effectiveness, and environmental sustainability in existing CPEC-related agricultural research.

5. Conclusion & Recommendations

CPEC offers significant opportunities to modernize Pakistan's agricultural value chains through improved infrastructure and regional connectivity. Realizing these benefits requires stronger institutional frameworks, better market governance, expanded investment in logistics, cold-chain systems, agro-processing, and value chain integration, while ensuring greater participation of smallholder farmers. These measures will promote inclusive agricultural growth, improve market efficiency, and maximize the long-term developmental benefits of CPEC.

Keywords: China–Pakistan Economic Corridor (CPEC); agricultural value chains; market linkages; transport infrastructure; institutional reforms; regional development; Pakistan

Rainfall and Production Drivers of Sugarcane Productivity in Pakistan: Evidence from an ARDL Cointegration Analysis

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1. Introduction

Sugarcane is a strategic cash crop that contributes significantly to Pakistan's agricultural economy, rural livelihoods, and the domestic sugar industry. However, productivity growth remains constrained by climatic variability, institutional limitations, and inefficient input utilization. Previous studies have largely examined climatic and production-related factors separately, providing limited evidence on their combined effects. This study integrates these determinants within a unified econometric framework to generate policy-relevant evidence for sustainable sugarcane productivity.

2. Objectives

This study investigates the long-run and short-run relationships between sugarcane productivity and key determinants, including rainfall, agricultural credit, fertilizer consumption, and pesticide use, to identify the principal drivers of sustainable productivity growth in Pakistan.

3. Methodology

Annual time-series data covering 1990–2025 were analyzed using the Autoregressive Distributed Lag (ARDL) cointegration approach. Sugarcane yield per hectare was used as the dependent variable, while rainfall, agricultural credit, fertilizer consumption, and pesticide use served as explanatory variables. Diagnostic, specification, and stability tests were performed to ensure model reliability, and the Error Correction Model (ECM) estimated short-run adjustment dynamics.

4. Results

The findings confirm a stable long-run equilibrium relationship between sugarcane productivity and its determinants. Agricultural credit emerged as the most significant production-related factor, indicating the importance of institutional finance in supporting productivity-enhancing investments. Rainfall also had a significant positive effect, emphasizing the continued dependence of sugarcane production on favorable climatic conditions. Pesticide use exhibited a positive but weakly significant association, whereas fertilizer consumption showed a negative and statistically insignificant relationship, suggesting that balanced nutrient management is more important than increased fertilizer use. The ECM indicated that approximately 38.2% of short-run disequilibrium adjusts toward long-run equilibrium annually, while diagnostic tests confirmed model robustness.

5. Conclusion & Recommendations

Improving sugarcane productivity requires expanding farmers' access to institutional credit, promoting efficient nutrient and crop protection practices, and strengthening climate-resilient production systems. Policymakers should integrate financial support with sustainable input management and climate adaptation strategies to enhance long-term productivity, resilience, and sustainability of Pakistan's sugarcane sector.

Keywords: Sugarcane yield; Institutional credit; Rainfall; Agricultural productivity; ARDL cointegration; Pakistan

Agricultural Inputs Associated with Wheat Productivity in Pakistan: Evidence from an ARDL Co-integration Analysis.

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1. Introduction

Wheat is Pakistan's principal staple crop and plays a fundamental role in national food security, rural livelihoods, and agricultural development. However, wheat productivity remains below its potential due to climate variability, inefficient input utilization, and production constraints. Existing studies have generally examined climatic and production-related factors separately, providing limited evidence of their combined influence on wheat productivity. This study investigates the long-run and short-run relationships between agricultural inputs, rainfall, and wheat productivity in Pakistan.

2. Objectives

To examine the long-run and short-run effects of rainfall, agricultural credit, fertilizer use, pesticide use, and cultivated area on wheat productivity and provide evidence-based policy recommendations for sustainable wheat production.

3. Methodology

Annual time-series data covering 1990–2025 were analyzed using the Autoregressive Distributed Lag (ARDL) co-integration approach. Wheat yield per hectare was used as the dependent variable, while rainfall, agricultural credit, fertilizer use, pesticide use, and cultivated area served as explanatory variables. Diagnostic, specification, and stability tests were conducted to ensure model reliability.

4. Results

The findings confirm a stable long-run equilibrium relationship between wheat productivity and the selected variables. Cultivated area emerged as the only statistically significant determinant, indicating that efficient land utilization is critical for improving productivity. Agricultural credit and fertilizer use showed positive but statistically insignificant effects, whereas rainfall and pesticide use exhibited negative, insignificant relationships. The error correction model revealed that approximately 55% of short-run disequilibrium adjusts annually toward long-run equilibrium. Diagnostic tests confirmed the robustness and stability of the estimated model.

5. Conclusion & Recommendations

Sustainable improvements in wheat productivity require efficient land management, enhanced input-use efficiency, climate-resilient production practices, strengthened agricultural extension services, and improved access to institutional support. Integrated policies promoting resource-efficient farming and climate adaptation will enhance wheat productivity, strengthen food security, and support sustainable agricultural development in Pakistan.

Keywords: Wheat productivity; Agricultural inputs; Rainfall; ARDL co-integration; Time-series analysis; Pakistan.

Rainfall and Production Determinants of Rice Productivity in Pakistan:

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1. Introduction

Rice is one of Pakistan's most important food and cash crops, contributing substantially to food security, rural livelihoods, and export earnings. However, productivity growth remains constrained by rainfall variability, inefficient use of production inputs, and management challenges. Previous studies have generally examined climatic and production-related determinants separately, providing limited evidence on their combined effects within a unified empirical framework. This study investigates the joint influence of rainfall and key agricultural inputs on rice productivity to generate evidence for sustainable agricultural development and informed policymaking in Pakistan.

2. Objectives

To examine the long-run and short-run relationships between rice productivity and rainfall, agricultural credit, fertilizer consumption, pesticide use, and cultivated area, and to identify the principal determinants of sustained productivity improvement.

3. Methodology

Annual time-series data for Pakistan covering 1990–2025 were analyzed using the Autoregressive Distributed Lag (ARDL) cointegration approach. Rice yield per hectare served as the dependent variable, while rainfall, agricultural credit, fertilizer consumption, pesticide use, and cultivated area were included as explanatory variables. Diagnostic, specification, and parameter stability tests were performed to verify the adequacy and robustness of the estimated model.

4. Results

The findings confirm a stable long-run equilibrium relationship between rice productivity and its determinants. Cultivated area emerged as the only statistically significant long-run production-related factor, highlighting the importance of efficient land utilization. Rainfall exhibited a positive effect and remained statistically significant at the 10% level, emphasizing the continued importance of favorable climatic conditions. Agricultural credit, fertilizer consumption, and pesticide use showed positive but statistically insignificant coefficients, suggesting that productivity gains depend more on efficient resource utilization and improved farm management than on increased input use alone. The Error Correction Model indicated that approximately 82.8% of short-run disequilibrium is corrected within one year, demonstrating rapid adjustment toward long-run equilibrium. Diagnostic and stability tests confirmed the reliability of the ARDL model.

5. Conclusion & Recommendations

Sustainable improvements in rice productivity require efficient land management, climate-resilient water management, balanced nutrient application, integrated pest management, strengthened agricultural extension services, and improved resource-use efficiency. These measures will enhance rice productivity, strengthen food security, and support sustainable agricultural development in Pakistan.

Keywords: Rice productivity; Rainfall; Agricultural inputs; ARDL cointegration; Time-series analysis; Pakistan.

Behavioral Factors Influencing Consumers' Online Purchasing Behavior Toward Agricultural Products in Pakistan

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1. Introduction

Rapid digitalization is transforming agricultural markets and consumer purchasing in Pakistan. However, evidence on factors influencing online purchases of agricultural products remains limited. This study examines consumers' online purchasing behavior using the Unified Theory of Acceptance and Use of Technology (UTAUT) framework, providing insights for strengthening digital agriculture and e-commerce.

2. Objectives

To investigate the effects of perceived usefulness, perceived ease of use, trust, perceived risk, price value, social influence, hedonic motivation, facilitating conditions, and socioeconomic factors on consumers' online purchasing behavior toward agricultural products in Pakistan.

3. Methodology

Quantitative research design was employed using primary data collected from 220 respondents through a structured questionnaire and convenience sampling. Descriptive statistics were analyzed using SPSS, while SmartPLS 4 was used to estimate the measurement and structural models through Partial Least Squares Structural Equation Modeling (PLS-SEM). Reliability, convergent validity, and structural model fitness were assessed using standard evaluation criteria.

4. Results

The measurement model demonstrated satisfactory reliability and validity, with composite reliability values exceeding recommended thresholds and average variance extracted (AVE) values above 0.50. The structural model explained 53.6% of the variation in online purchasing behavior. Hedonic motivation emerged as the strongest positive predictor, indicating that enjoyable shopping experiences significantly encourage online purchases of agricultural products. Price value also had a significant positive influence, suggesting that competitive pricing and perceived value for money enhance purchase intentions. In contrast, perceived usefulness, perceived ease of use, trust, perceived risk, facilitating conditions, social influence, and socioeconomic factors showed no statistically significant direct effects.

5. Conclusion & Recommendations

Consumers' online purchasing behavior for agricultural products is primarily driven by shopping experience and perceived economic value rather than technological or social factors. Agribusinesses and e-commerce platforms should enhance user experience, offer competitive pricing, and implement attractive promotional strategies. Policymakers should strengthen digital infrastructure, promote agricultural e-commerce adoption, and support secure online marketplaces to accelerate the digital transformation of Pakistan's agricultural sector.

Keywords: Agricultural e-commerce; Online purchasing behavior; Behavioral factors; UTAUT; PLS-SEM; Pakistan.

Understanding Young Consumers Attitude Towards Reduction of Food Wastage in South Punjab

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1. Introduction:

Food waste is a major global challenge with significant ethical, economic, social, and environmental consequences. This study examines the sociopsychological factors influencing young consumers' intentions and behaviors toward food waste reduction in South Punjab, Pakistan. Guided by the Theory of Planned Behavior (TPB), the study considers attitude, perceived behavioral control, social influence, personal norms, moral norms, injunctive norms, and awareness as potential determinants of food waste reduction behavior.

2. Objectives:

The study aims to identify the key factors influencing young consumers' intentions to reduce food waste and examine the relationship between behavioral intention and actual food waste reduction practices.

3. Methodology:

A quantitative research design was employed using a structured questionnaire administered to young consumers in South Punjab. The proposed conceptual framework was tested using Structural Equation Modeling (SEM) through AMOS. Confirmatory Factor Analysis (CFA) was conducted to assess the reliability and validity of the measurement constructs.

4. Results:

The findings demonstrate that attitude and perceived behavioral control significantly influence intentions to reduce food waste. Moral norms and social influence also contribute directly and indirectly to behavioral intentions through their effects on attitudes and perceived control. Awareness alone does not significantly influence intention directly but contributes indirectly to behavioral change. Behavioral intention emerged as the strongest predictor of actual food waste reduction behavior.

5. Conclusion & Recommendations:

The findings support and extend the TPB by incorporating awareness and moral norms into the behavioral framework. Effective interventions should promote positive attitudes, strengthen practical behavioral control, enhance social and moral influences, and translate awareness into action through targeted educational and community-based initiatives.

Keywords: Young Consumers; Food Waste Reduction; Theory of Planned Behavior; Moral Norms; Behavioral Intention

Determinants of Off-Farm Income Diversification and its Role in Risk Management among Smallholder Farmers in Punjab, Pakistan

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1. Introduction:

Agricultural households in Pakistan increasingly face production risks, market uncertainty, price fluctuations, and climate-related shocks that threaten farm income stability. Off-farm income diversification provides an important livelihood strategy for reducing vulnerability and strengthening household resilience. This study examines the determinants of farmers' participation in off-farm income activities and assesses their contribution to household welfare and agricultural risk management.

2. Objectives:

The study aims to identify factors influencing participation in off-farm income activities and evaluate the perceived contribution of income diversification to household welfare, income stability, and management of agricultural risks among smallholder farmers.

3. Methodology:

Primary data were collected from 150 farming households using a structured questionnaire. Descriptive statistics, reliability analysis, Likert-scale analysis, and Binary Logistic Regression were employed. The regression model identified socioeconomic and farm-level factors influencing participation, while Likert-scale responses assessed farmers' perceptions of livelihood and risk-management benefits.

4. Results:

The findings indicate substantial participation in off-farm activities to supplement agricultural earnings and improve economic security. Operational farm size and availability of non-farm employment opportunities significantly increased participation, whereas annual farm income had a significant negative association, indicating lower dependence on off-farm sources among households with higher farm earnings. Respondents perceived off-farm income as an effective mechanism for improving income stability, consumption, savings, living standards, and household expenditures. It also reduced vulnerability to crop failure, adverse weather, price volatility, and income uncertainty.

5. Conclusion & Recommendations:

Off-farm income diversification strengthens household resilience and provides an effective mechanism for managing agricultural risks. Policies should expand rural education, skills development, credit access, and non-farm employment opportunities to promote sustainable livelihoods and reduce vulnerability among smallholder farmers.

Keywords: Off-Farm Income; Income Diversification; Rural Livelihoods; Risk Management; Farming Households; Binary Logistic Regression; Pakistan

Genetic Diversity and Performance Analysis of Exotic Sweet Corn (*Zea mays L. saccharata*) Genotypes in Faisalabad

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1. Introduction:

Sweet corn (*Zea mays L. saccharata*) is an economically valuable crop consumed as a vegetable and recognized for its high sugar content and nutritional quality. However, research on sweet corn genetic resources remains limited in Pakistan. This study evaluated exotic sweet corn genotypes for genetic diversity, agronomic performance, nutritional quality, and stress tolerance under Faisalabad conditions.

2. Objectives:

The study aimed to assess genetic variability and performance among exotic sweet corn genotypes and identify promising hybrids with superior yield, nutritional characteristics, and physiological resilience for future breeding programs.

3. Methodology:

Four exotic genotypes, YSC-811, WSC-602, WSC-99, and WSC-01, were hybridized to develop eleven crosses. Parents and hybrids were evaluated under a Randomized Complete Block Design with three replications. Morphological, yield, nutritional, biochemical, and antioxidant traits were recorded. Principal component analysis and hierarchical clustering were used to characterize genetic diversity.

4. Results:

Significant genetic variation was observed among genotypes for most traits. Plant height ranged from 133.33 cm in YSC-811 to 150.13 cm in WSC-602 × WSC-99. YSC-811 × WSC-01 and WSC-01 × YSC-811 showed superior cob weight, grain weight, and 100-grain weight, while WSC-602 recorded the highest shelling percentage. WSC-01 × YSC-811 demonstrated superior nutritional composition, whereas YSC-811 × WSC-602 exhibited the highest catalase, superoxide dismutase, and peroxidase activities. Principal component analysis explained 65.8% and 70.4% variation in morphological and physio-biochemical traits, respectively.

5. Conclusion & Recommendations:

YSC-811 × WSC-01, WSC-01 × YSC-811, and YSC-811 × WSC-602 emerged as promising genotypes combining yield, nutritional quality, and stress tolerance. Multi-environment testing and molecular breeding are recommended to accelerate development of resilient sweet corn hybrids for Pakistan.

Keywords: Sweet Corn; Genetic Diversity; Yield; Nutritional Quality; Performance; Stress Tolerance

SECTION III

3. Technology and Data-Driven Agriculture

7 Abstracts

Digital Aquaculture for Economic Transformation in Indonesia's Seaweed Farming: Challenges, Prospects, and Policy Recommendations

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1. Introduction

Indonesia is a leading tropical seaweed producer supporting coastal livelihoods, exports, and the blue economy. However, productivity, climate variability, disease, water quality, fragmented supply chains, limited value addition, and price volatility constrain growth. Digital aquaculture offers opportunities to improve production efficiency, sustainability, market competitiveness, and long-term resilience of Indonesia's seaweed industry.

2. Objectives

This study evaluates the potential of digital aquaculture to transform Indonesia's seaweed farming sector by enhancing productivity, environmental sustainability, value-chain efficiency, and export competitiveness while identifying implementation challenges and policy priorities.

3. Methodology

The study employs a narrative review combined with policy and trade analysis. Evidence was synthesized from peer-reviewed literature, government reports, and international databases, including the Food and Agriculture Organization (FAO), UN Comtrade, ITC Trade Map, and Statistics Indonesia (BPS). The review assesses the application of digital technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), Geographic Information Systems (GIS), remote sensing, blockchain, and digital marketplaces.

4. Results

The findings indicate that digital aquaculture can improve environmental monitoring, disease surveillance, production planning, product traceability, and supply-chain management. These technologies enhance farm productivity, quality assurance, value-added processing, and export competitiveness. However, adoption is constrained by inadequate digital infrastructure, limited digital literacy, insufficient investment, fragmented institutional coordination, weak extension services, and unequal technology access among coastal communities.

5. Conclusion & Recommendations

Digital aquaculture provides a strategic pathway for transforming Indonesia's seaweed farming into a productive, resilient, and globally competitive industry. Policymakers should strengthen digital infrastructure, expand extension and training services, develop integrated digital platforms, encourage public-private partnerships, and promote value-added processing to accelerate sustainable blue economy development and improve coastal livelihoods.

Keywords: Digital aquaculture; seaweed farming; Artificial Intelligence; Internet of Things; blue economy; export competitiveness; Indonesia.

Smart Farming for Sustainable and Water-Efficient Crop Production

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1. Introduction

Increasing water scarcity and inefficient resource utilization pose major challenges to sustainable agricultural production. Conventional irrigation systems consume substantial amounts of water while often failing to optimize crop growth and resource efficiency. Smart farming technologies integrating the Internet of Things (IoT) with aeroponic cultivation offer a promising solution by enabling real-time environmental monitoring and automated nutrient management. This study evaluates the effectiveness of an IoT-enabled aeroponic system for improving water-use efficiency and crop productivity under controlled growing conditions.

2. Objectives

To assess the performance of an IoT-based aeroponic cultivation system in enhancing water-use efficiency, optimizing nutrient delivery, improving crop biomass production, and supporting sustainable agricultural production.

3. Methodology

An automated aeroponic system equipped with IoT sensors was developed to continuously monitor temperature, humidity, and nutrient solution levels. Plant roots were suspended within a mist chamber and supplied with nutrient-rich mist through a feedback-controlled delivery system. Sensor data were used to regulate misting frequency and nutrient application according to real-time environmental conditions. System performance was evaluated by comparing water consumption and plant biomass production with conventional irrigation practices.

4. Results

The IoT-enabled aeroponic system reduced water consumption by more than 80% compared with conventional irrigation while maintaining optimal plant growth conditions. Improved root aeration and precise nutrient delivery enhanced nutrient uptake, resulting in approximately 57% greater biomass production. Continuous sensor monitoring enabled early detection of nutrient deficiencies and timely corrective actions, improving overall system efficiency and crop performance. The findings demonstrate the potential of smart farming technologies to increase agricultural productivity while conserving critical water resources.

5. Conclusion & Recommendations

IoT-integrated aeroponic farming provides an effective and sustainable approach for water-efficient crop production, particularly in water-scarce regions and urban agriculture. Future research should integrate artificial intelligence, remote sensing, and predictive analytics to further optimize resource management and decision-making. Wider adoption of smart farming technologies can enhance agricultural sustainability, strengthen climate resilience, and improve food production under increasing resource constraints.

Keywords: Precision agriculture; Aeroponic farming; Internet of Things (IoT); Sustainable crop production; Water-use efficiency.

Bridging the Digital Divide for Climate Mitigation: A Review of Smallholder Empowerment and Equity in Digital Agriculture

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1. Introduction

Digital technologies are increasingly recognized as essential tools for advancing climate change mitigation and promoting sustainable agricultural development. Mobile advisory services, climate information systems, precision agriculture, digital finance, and data-driven decision-support tools can improve resource-use efficiency and strengthen climate-smart agriculture among smallholder farmers. However, unequal access to digital infrastructure, financial resources, technical skills, and data governance mechanisms continues to widen the digital divide, limiting the participation of vulnerable farming communities in the digital transformation of agriculture. This review synthesizes current evidence on digital inclusion, equity, and smallholder empowerment in the context of climate change mitigation.

2. Objectives

To examine the role of digital technologies in supporting climate mitigation, assess barriers to digital inclusion among smallholder farmers, and identify strategies for promoting equitable and climate-resilient digital agriculture.

3. Methodology

A structured literature review was conducted using 50 peer-reviewed articles published between 2010 and 2025. The selected studies were synthesized across five thematic areas: digital climate information services, climate-smart agricultural technologies, digital inclusion and access barriers, gender and social inclusion, and data governance and responsible digital innovation.

4. Results

The review demonstrates that digital technologies enhance climate mitigation by improving access to climate information, strengthening resource management, facilitating adoption of climate-smart practices, and expanding participation in climate-oriented agricultural markets. However, persistent barriers including inadequate digital infrastructure, affordability constraints, limited digital literacy, gender inequalities, weak institutional support, and insufficient farmer control over agricultural data continue to restrict equitable access and technology adoption. The findings emphasize that technological innovation alone cannot ensure inclusive outcomes without supportive institutional and policy frameworks.

5. Conclusion & Recommendations

Bridging the digital divide requires investments in digital infrastructure, affordable connectivity, farmer capacity development, gender-inclusive digital policies, participatory technology design, and responsible agricultural data governance. Integrating digital inclusion into national climate and agricultural policies will empower smallholder farmers, strengthen climate resilience, promote equitable technology adoption, and support sustainable and inclusive agri-food systems.

Keywords: Digital inclusion; Climate change mitigation; Digital agriculture; Climate-smart agriculture; Smallholder farmers; Equity

Green Synthesis and Characterization of Nanoparticles for their Potential Applications against Fusarium Wilt in Tomatoes

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1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the world's most important vegetable crops, valued for its nutritional and economic significance. However, its production is severely constrained by Fusarium wilt, caused by *Fusarium oxysporum*, which persists in soil and causes substantial yield and quality losses. Conventional fungicides often raise concerns regarding environmental contamination and pathogen resistance, highlighting the need for sustainable disease management strategies. This study investigates the potential of plant-mediated green synthesized nanoparticles as eco-friendly antifungal agents for controlling Fusarium wilt in tomato.

2. Objectives

To synthesize and characterize zinc oxide and copper-based nanoparticles using plant extracts, evaluate their antifungal activity against *Fusarium oxysporum* under laboratory conditions, and assess their efficacy in suppressing Fusarium wilt under greenhouse conditions.

3. Methodology

Green synthesis of zinc oxide and copper-based nanoparticles was performed using selected plant extracts. The synthesized nanoparticles were characterized through UV–Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), and Scanning Electron Microscopy (SEM). Antifungal activity was evaluated using the poisoned food technique under in vitro conditions, while greenhouse experiments assessed disease suppression and plant growth responses. Data were analyzed using analysis of variance (ANOVA) at a 5% significance level.

4. Results

Characterization confirmed the successful synthesis and nanoscale properties of both zinc oxide and copper-based nanoparticles. Laboratory assays demonstrated significant inhibition of *Fusarium oxysporum* mycelial growth compared with the untreated control. Greenhouse evaluations further showed a substantial reduction in Fusarium wilt severity, accompanied by improved plant growth and vigor in treated tomato plants. Both nanoparticle formulations exhibited promising antifungal efficacy, indicating their potential as environmentally friendly alternatives to conventional chemical fungicides.

5. Conclusion & Recommendations

Green synthesized zinc oxide and copper-based nanoparticles offer an effective and sustainable approach for managing Fusarium wilt in tomato. Their ability to suppress pathogen growth and reduce disease severity highlights their potential for integrated disease management. Future research should focus on multi-location field validation, optimization of application rates, long-term environmental safety assessments, and large-scale commercialization to support sustainable tomato production.

Keywords: Green synthesis; Zinc oxide nanoparticles; Copper nanoparticles; *Fusarium oxysporum*; Fusarium wilt; Tomato (*Solanum lycopersicum* L.)

Ecological Farming Practices and Income Diversity among Citrus Farmers in Punjab, Pakistan

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1. Introduction

Agriculture is a cornerstone of Pakistan's economy, providing livelihoods for nearly two-thirds of the population either directly or indirectly. Growing environmental concerns and the need for sustainable agricultural production have increased interest in ecological farming practices that enhance environmental sustainability while improving farm profitability.

2. Objectives

To identify the socioeconomic, farm-level, institutional, and psychological factors influencing the adoption of ecological farming practices among citrus farmers and to estimate their impact on farm income.

3. Methodology

Primary data were collected from citrus farmers in Punjab, Pakistan, using a structured survey. An Endogenous Switching Regression (ESR) model was employed to account for selection bias and estimate both the determinants of adoption and the income effects of ecological farming practices. The Average Treatment Effect on the Treated (ATT) was estimated to compare the income of adopters with that of non-adopters.

4. Results

The findings indicate that access to agricultural extension services, higher educational attainment of household heads, and positive risk-taking attitudes significantly increase the likelihood of adopting ecological farming practices. Conversely, larger landholdings, greater labor availability, longer distances to markets, and participation in off-farm activities negatively influence adoption. These results highlight the economic benefits of environmentally sustainable farming while emphasizing the importance of institutional support in facilitating adoption.

5. Conclusion & Recommendations

Promoting ecological farming practices can enhance both environmental sustainability and farm income among citrus growers. Policymakers should strengthen agricultural extension services, improve farmer education and training, facilitate access to technical support, and encourage awareness programs to accelerate adoption. These interventions will contribute to sustainable citrus production, diversified rural incomes, and resilient agricultural development in Punjab, Pakistan.

Keywords: Ecological farming practices; Citrus; Income diversity; Endogenous Switching Regression; Sustainable agriculture; Punjab, Pakistan.

Assessment of Germplasm for nutritional profile using spring wheat

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1. Introduction

Spring wheat (*Triticum aestivum* L.) is a major cereal crop and an important source of carbohydrates, protein, dietary fiber, and essential nutrients. Improving grain nutritional quality requires the identification of genetically diverse germplasm with superior quality traits. Assessing genetic variability and relationships among wheat genotypes provides valuable information for selecting suitable parental lines in breeding programs aimed at enhancing grain quality and productivity. This study evaluated the genetic diversity and nutritional characteristics of selected spring wheat germplasm to identify promising genotypes for future crop improvement.

2. Objectives

To assess genetic diversity among spring wheat genotypes based on agronomic and nutritional traits, identify superior germplasm for grain quality improvement, and determine suitable parental lines for wheat breeding programs.

3. Methodology

Fourteen hexaploid wheat genotypes were evaluated using nine quantitative agronomic traits together with laboratory analyses of grain nutritional characteristics, including grain diameter, grain weight, gluten, protein, fiber, fat, and starch contents. Genetic diversity was assessed using principal component analysis (PCA) and cluster analysis to classify genotypes and identify trait associations contributing to variation.

4. Results

PCA revealed that the first seven principal components explained more than 88% of the total genetic variation. Cluster analysis grouped the genotypes into four distinct clusters, indicating substantial genetic diversity. Grain diameter, grain weight, gluten content, protein content, fiber, fat, and starch were the major contributors to genetic variation. Genotypes 88146, Fareed-06, 6317, and 88132 exhibited maximum genetic divergence and demonstrated superior potential as parental lines for quality improvement.

5. Conclusion & Recommendations

The evaluated spring wheat germplasm possesses considerable genetic variability for nutritional and grain quality traits. The identified diverse genotypes provide valuable breeding material for developing nutritionally superior, high-yielding wheat cultivars. Future breeding programs should exploit crosses among genetically distant parents to broaden the genetic base, enhance grain nutritional quality, and improve food and nutritional security in Pakistan.

Keywords: Spring wheat, Genetic diversity, Nutritional quality, Principal component analysis, Cluster analysis, Wheat breeding.

Modification in the Kraft Method for the Green Synthesis of Epoxy Resin from Agricultural Waste.

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1. Introduction

Agricultural waste generation has become a major environmental challenge, contributing to greenhouse gas emissions, soil degradation, and resource wastage. However, lignocellulosic residues represent a valuable renewable feedstock for producing high-value industrial materials. Epoxy resin is extensively used in coatings, adhesives, composites, and electronics, yet Pakistan relies heavily on costly imports. Developing sustainable methods for producing bio-based epoxy resin from agricultural waste can reduce environmental pollution while promoting a circular bioeconomy. This study proposes a modified Kraft process integrated with biotechnology to synthesize lignin-derived epoxy resin through an environmentally friendly approach.

2. Objectives

To develop a modified Kraft method for extracting lignin from agricultural waste, evaluate the biotechnological depolymerization of lignin for epoxy resin production, and characterize the resulting bio-based intermediates for sustainable industrial applications.

3. Methodology

Agricultural residues, particularly wood shavings, were subjected to a modified Kraft pulping process using sodium hydroxide under controlled temperature and pressure to separate lignin from cellulose and hemicellulose. The extracted Kraft lignin was fractionated and biologically depolymerized using *Bacillus subtilis* to produce lignin-derived monomers. The synthesized intermediates were characterized using Fourier Transform Infrared (FTIR) spectroscopy and Nuclear Magnetic Resonance (NMR) spectroscopy to verify their chemical structure and suitability for epoxy resin production.

4. Results

The modified Kraft process efficiently recovered lignin from agricultural waste, while biological depolymerization generated valuable aromatic monomers suitable for bio-based epoxy resin synthesis. FTIR and NMR analyses confirmed the structural integrity of the extracted lignin derivatives and demonstrated the effectiveness of the environmentally friendly biotechnological approach. The proposed method reduced dependence on harsh chemical treatments while enhancing resource recovery from agricultural residues.

5. Conclusion & Recommendations

The modified Kraft method combined with microbial lignin depolymerization provides a sustainable pathway for converting agricultural waste into value-added epoxy resin precursors. This green approach supports waste valorization, reduces environmental pollution, and promotes renewable industrial materials. Future research should optimize process efficiency, integrate artificial intelligence for process optimization, and evaluate large-scale commercial production to strengthen Pakistan's sustainable bio-based chemical industry.

Keywords: Agricultural waste, Kraft method, Bio-based epoxy resin, Lignin valorization, Green synthesis, Circular bioeconomy.

SECTION IV

4. Equity, Policy, and Institutional Innovation

17 Abstracts

Impact of Women's Empowerment on Sustainable Development in District Faisalabad

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1. Introduction

Women's empowerment is widely recognized as a fundamental driver of sustainable development, particularly in developing countries where gender inequality continues to limit social and economic progress. Empowering women through education, employment, decision-making, ownership of assets, and access to productive resources contributes to improved household welfare, poverty reduction, and environmental sustainability. Despite ongoing policy efforts, significant gender disparities persist in Pakistan, restricting women's contributions to sustainable development. This study examines the impact of women's empowerment on key dimensions of sustainable development, including household welfare, income generation, social integration, and environmental awareness in District Faisalabad.

2. Objectives

To evaluate the effect of women's empowerment on sustainable development, assess its influence on household welfare, income generation, social integration, and environmental awareness, and identify the major barriers limiting women's empowerment.

3. Methodology

A quantitative research design was employed using primary data collected from women in District Faisalabad through a structured questionnaire. Descriptive statistics were used to summarize respondents' socioeconomic characteristics, while regression analysis examined the relationship between women's empowerment and multiple dimensions of sustainable development.

4. Results

The findings revealed that women's empowerment had a statistically significant and positive effect on household welfare, income generation, social participation, and environmental awareness. Women with greater decision-making authority, educational attainment, and economic participation demonstrated higher contributions to household well-being and community development. The analysis also identified limited education, restricted access to resources, cultural constraints, and inadequate economic opportunities as major barriers to empowerment.

5. Conclusion & Recommendations

Strengthening women's empowerment is essential for achieving inclusive and sustainable development. Policies should prioritize girls' education, women's economic participation, access to financial resources, property rights, leadership opportunities, and gender-responsive development programs. Enhancing institutional support and promoting gender-inclusive policies will accelerate progress toward the Sustainable Development Goals while improving household resilience, social equity, and long-term economic development in Pakistan.

Keywords: Women's empowerment, Sustainable development, Gender equality, Household welfare, Income generation, Pakistan.

Beyond the Blackboard: Co-Designing Agricultural Extension Curricula with Indigenous Ecological Knowledge in Rural Punjab

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1. Introduction

Punjab's agricultural extension system has traditionally emphasized standardized technologies, often overlooking Indigenous ecological knowledge. Farmers possess valuable knowledge of soil fertility, water management, crop rotation, seasonal indicators, and pest control. This study examines whether integrating Indigenous knowledge into extension curricula can strengthen farmer trust, promote sustainable practices, and enhance resilience to climate variability.

2. Objectives

To document Indigenous ecological knowledge related to soil, water, and crop management; identify complementarities and conflicts between traditional knowledge and formal extension recommendations; develop a hybrid extension curriculum; and evaluate its impact on farmer trust, technology adoption, and sustainable resource use.

3. Methodology

A participatory action research approach was implemented across selected districts of Punjab. Semi-structured interviews and focus group discussions with experienced farmers, women cultivators, and extension personnel documented Indigenous farming practices. A hybrid extension curriculum was co-developed by local knowledge holders and agricultural scientists and piloted in selected villages. Changes in farmer trust, technology adoption, and perceived relevance of extension services were assessed through pre- and post-intervention surveys. Difference-in-differences analysis and thematic qualitative analysis were employed to evaluate program effectiveness.

4. Results

The hybrid extension approach is expected to enhance farmer trust, improve adoption of water-conserving and climate-resilient farming practices, and strengthen sustainable resource management. Smallholder and women farmers are anticipated to benefit most from locally adapted recommendations. The study also identifies opportunities to harmonize traditional ecological knowledge with scientific extension while addressing conflicts in management practices.

5. Conclusion & Recommendations

Integrating Indigenous ecological knowledge into agricultural extension can improve farmer participation, resource-use efficiency, and climate resilience. Policymakers should institutionalize partnerships between extension agencies and community knowledge holders, strengthen participatory extension approaches, and develop locally adapted advisory services that combine scientific innovations with validated traditional practices to promote sustainable agriculture in Punjab.

Keywords: Indigenous ecological knowledge, Agricultural extension, Participatory approaches, Sustainable agriculture, Climate resilience, Punjab.

Who Gets Heard? Structural and Linguistic Barriers to Indigenous Farmers' Engagement with State Extension Services in Muzaffargarh, Punjab

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1. Introduction

Inclusive agricultural extension is vital for sustainable rural development, yet Indigenous farming communities in Punjab face structural, linguistic, cultural, and communication barriers. This study examines factors limiting Indigenous farmers' participation in government extension services in Muzaffargarh District and explores approaches for making extension delivery more inclusive, culturally responsive, accessible, and farmer centered.

2. Objectives

To identify the structural, linguistic, and relational barriers affecting Indigenous farmers' access to agricultural extension services; evaluate the compatibility of extension delivery with Indigenous languages and farming practices; assess stakeholder perceptions; and develop policy recommendations for inclusive extension systems.

3. Methodology

A mixed-methods research design was adopted in Muzaffargarh District. Quantitative data were collected through structured questionnaires administered to Indigenous farming households, while qualitative information was gathered through focus group discussions with farmers and extension officers. Purposive sampling ensured representation across different communities. Quantitative data were analyzed using descriptive statistics, whereas thematic analysis was applied to qualitative findings to identify recurring issues related to language, trust, cultural compatibility, and service delivery.

4. Results

The study identified language barriers, cultural mismatches, institutional constraints, historical distrust, and poor alignment between extension services and traditional farming systems as the principal factors limiting farmer engagement. Inappropriate communication methods, inaccessible service schedules, and limited participation of Indigenous communities further reduced technology adoption. A clear disconnect was observed between institutional perceptions of service effectiveness and farmers' actual experiences.

5. Conclusion & Recommendations

Developing inclusive agricultural extension requires recruiting and training Indigenous extension personnel, translating advisory materials into local languages, adopting participatory communication approaches, aligning extension activities with local agricultural calendars, and strengthening institutional coordination. These measures can improve farmer trust, increase technology adoption, and promote equitable and sustainable agricultural development among Indigenous farming communities in Punjab.

Keywords: Indigenous farming communities, Agricultural extension, Language barriers, Cultural inclusion, Participatory extension, Punjab.

Institutional Innovation for Equitable Climate Governance: A Review of Policy Frameworks and Intergenerational Approaches

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1. Introduction

Climate change requires institutional innovation alongside technological advancement to achieve equitable and sustainable development. However, fragmented policies, short-term priorities, and limited intergenerational perspectives constrain effective climate governance. This review examines emerging institutional approaches that strengthen policy coherence, incorporate intergenerational equity, and support inclusive, accountable, and long-term climate action.

2. Objectives

To review contemporary literature on institutional innovation in climate governance, identify key governance gaps, evaluate policy frameworks that promote intergenerational equity, and develop recommendations for strengthening equitable and long-term climate policymaking.

3. Methodology

A narrative literature review was conducted using interdisciplinary research on climate governance, institutional innovation, public policy, and intergenerational equity. The review synthesized evidence from peer-reviewed publications, including the Futures special issue on innovation and climate change (2022), the International IDEA report on institutional innovations for future generations, and related policy literature. Thematic analysis was employed to identify recurring concepts concerning governance effectiveness, institutional learning, policy integration, and long-term decision-making.

4. Results

The review demonstrates that technological innovation alone is insufficient for achieving climate justice and sustainable transitions. Effective governance depends on institutional arrangements that promote transparency, accountability, policy continuity, and participatory decision-making. Major gaps include inadequate integration of technological and behavioral innovation, limited attention to institutional drivers of climate transitions, and insufficient operationalization of intergenerational equity. Emerging mechanisms such as future generations institutions, constitutional safeguards, parliamentary oversight, and participatory governance offer promising pathways for strengthening climate resilience.

5. Conclusion & Recommendations

Achieving equitable climate governance requires institutional reforms that complement technological innovation. Policymakers should integrate intergenerational equity into climate policies, strengthen democratic accountability, encourage inclusive participation, and establish long-term governance mechanisms. Future interdisciplinary research should evaluate the effectiveness of institutional innovations across diverse political and socioeconomic contexts to advance climate justice and sustainable development.

Keywords: Climate governance, Institutional innovation, Intergenerational equity, Climate policy, Climate justice, Sustainable development.

Community-based Adaptation to Climate Change through Indigenous Knowledge: A Review of Local Resilience Pathways, Sustainable Practices, and Knowledge Integration

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1. Introduction

Climate change adaptation increasingly emphasizes community-based approaches that integrate Indigenous knowledge and local experiences. Indigenous communities possess valuable knowledge supporting environmental observation, sustainable resource management, agricultural adaptation, biodiversity conservation, and collective decision-making. This study reviews Indigenous contributions to community-based adaptation and identifies pathways for strengthening locally grounded climate resilience and adaptive capacity.

2. Objectives

The study aims to synthesize evidence on the contribution of Indigenous knowledge to climate adaptation, examine its role in strengthening community resilience and livelihoods, and assess opportunities for integrating Indigenous and scientific knowledge through participatory approaches.

3. Methodology

A structured review of 50 peer-reviewed research articles published between 2000 and 2025 was conducted. The literature was examined thematically to identify major contributions of Indigenous knowledge to climate forecasting, ecosystem management, agricultural adaptation, livelihood transformation, biodiversity conservation, and knowledge co-production.

4. Results

The review demonstrates that Indigenous knowledge provides valuable insights for responding to climate risks through locally developed forecasting systems, traditional farming practices, crop diversification, ecosystem-based management, and culturally embedded livelihood strategies. Community-based adaptation strengthens adaptive capacity through collective action, social learning, and context-specific decision-making. Evidence further indicates that combining Indigenous and scientific knowledge can improve the effectiveness, legitimacy, and sustainability of adaptation interventions. However, institutional barriers and limited recognition of Indigenous knowledge continue to constrain its wider integration.

5. Conclusion & Recommendations

Indigenous knowledge should be recognized as a dynamic and evolving knowledge system rather than a static collection of traditional practices. Climate adaptation policies should prioritize participatory approaches, strengthen community knowledge networks, and establish equitable mechanisms for knowledge co-production. Integrating Indigenous and scientific knowledge can promote inclusive, locally appropriate, and resilient adaptation pathways while strengthening sustainable agricultural and ecosystem management.

Keywords: Indigenous Knowledge; Community-Based Adaptation; Knowledge Co-production; Climate-Smart Agriculture; Ecosystem-Based Adaptation

Impact of Financial Constraints on Corporate Financial Policies under Economic Uncertainty: Evidence from Pakistan's Textile Sector

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1. Introduction

Financial constraints significantly influence corporate liquidity and financing decisions, particularly in emerging economies characterized by imperfect capital markets and macroeconomic uncertainty. Pakistan's textile sector has faced persistent financing challenges due to inflation, exchange-rate volatility, energy shortages, and the COVID-19 pandemic. However, limited evidence exists on the simultaneous effects of financial constraints on cash holdings and leverage and the moderating roles of profitability and economic uncertainty.

2. Objectives

This study examines the impact of financial constraints on corporate financial policies by assessing their effects on cash holdings and leverage. It further investigates whether profitability and economic uncertainty moderate these relationships among textile firms listed on the Pakistan Stock Exchange (PSX).

3. Methodology

Panel data from 25 textile firms listed on the PSX covering 2015–2025, comprising 275 firm-year observations, were analyzed. Financial constraints were measured using the Kaplan–Zingales (KZ) Index. Cash holdings and leverage were used as dependent variables, while profitability and COVID-19-related economic uncertainty were examined as moderating factors. The Hausman test was applied to select the appropriate fixed-effects or random-effects model. Data were obtained from the State Bank of Pakistan, Pakistan Bureau of Statistics, and firms' annual reports.

4. Results

Financial constraints significantly reduced cash holdings and increased leverage, indicating lower liquidity reserves and greater reliance on debt financing. Profitability weakened the negative effect on cash holdings and reduced dependence on leverage. The COVID-19 pandemic intensified financing pressures and increased precautionary cash-holding motives among financially constrained firms.

5. Conclusion & Recommendations

Financial constraints substantially shape corporate financial policies in Pakistan's textile sector. Firms should strengthen internal financial capacity, maintain adequate liquidity buffers, diversify financing sources, and adopt resilient financing strategies to withstand economic uncertainty.

Keywords: Financial Constraints, Cash Holdings, Leverage, Profitability, Economic Uncertainty, Textile Sector, Pakistan.

Impact of Corporate Social Responsibility on Firm Performance: Role of Enterprise Risk Management and Corporate Governance

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1. Introduction

Corporate Social Responsibility (CSR) has become an important strategic practice for improving organizational sustainability and firm performance. Although previous studies generally report a positive relationship between CSR and performance, limited evidence exists on the mediating role of Enterprise Risk Management (ERM) and the moderating role of Corporate Governance (CG), particularly in Pakistan's textile industry. This study addresses this gap by examining these interconnected relationships.

2. Objectives

The study examines the effect of CSR on firm performance and investigates whether ERM mediates this relationship and whether corporate governance strengthens the relationship among textile firms listed on the Pakistan Stock Exchange (PSX).

3. Methodology

A quantitative research approach was employed using balanced panel data from 20 textile firms listed on the PSX, comprising 120 firm-year observations for 2020–2025. Secondary data were obtained from company annual reports and PSX records. Firm performance was measured using Return on Assets (ROA), Return on Equity (ROE), and Tobin's Q, while CSR, ERM, and corporate governance were measured through disclosure indices. Hausman specification, panel regression, mediation, and moderation analyses were conducted using STATA.

4. Results

The findings indicate that CSR has a positive and significant effect on firm performance. CSR also significantly improves ERM, while ERM partially mediates the relationship between CSR and firm performance. Furthermore, corporate governance significantly strengthens the positive relationship between CSR and firm performance. The Hausman test supports the fixed-effects model as the appropriate estimation technique.

5. Conclusion & Recommendations

Integrating CSR with effective ERM and strong corporate governance enhances firm performance and organizational sustainability. Textile firms should strengthen CSR initiatives, risk management systems, and governance mechanisms to improve competitiveness and long-term performance in Pakistan.

Keywords: Corporate Social Responsibility; Enterprise Risk Management; Corporate Governance; Firm Performance; Textile Industry; Pakistan.

Legal Framework and Current State of International Freight Transportation in Azerbaijan

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1. Introduction

International freight transportation is a fundamental mechanism for global economic integration. Its importance extends beyond the cross-border movement of goods, providing infrastructure for international production chains, strengthening interregional cooperation, and supporting economic welfare. Lower transportation costs can increase trade volumes and export competitiveness. Previous studies by Behar and Venables, Hummels, Donaldson, and others suggest that a 1% reduction in transportation costs may increase exports by approximately 3–6%, and in some cases by 6–7%. Consequently, countries increasingly pursue policies designed to create favorable conditions for efficient international freight transportation and logistics.

2. Objectives

This study aims to examine the current state of international freight transportation in Azerbaijan, assess the country's strategic position within major international transport corridors, and evaluate the national and international legal frameworks governing freight activities. It further examines infrastructure development, transit performance, digitalization, major constraints, and prospects for strengthening Azerbaijan's role as a regional logistics hub.

3. Methodology

The study employs a qualitative and analytical approach based on an examination of national transport legislation, strategic policy documents, international conventions, infrastructure projects, and available statistical indicators. Particular attention is given to the Middle Corridor (Trans-Caspian International Transport Route), Baku–Tbilisi–Kars railway, Alat International Sea Trade Port, North–South Corridor, and Astara railway hub. The analysis also considers Azerbaijan's participation in TIR, CMR, ADR, COTIF, and TRACECA frameworks, as well as digital customs procedures and the Single Window system.

4. Results

Azerbaijan's favorable geoeconomic position enables it to function as a strategic bridge between Europe and Asia. Major infrastructure projects have strengthened freight connectivity and increased transit flows along regional and China–Central Asia–Europe routes. The Baku–Tbilisi–Kars railway and Alat Port have improved multimodal connectivity, while the North–South Corridor provides an alternative route connecting India and Russia. International freight transportation contributes to foreign currency earnings, sectoral value added, regional cooperation, and Azerbaijan's geopolitical importance by facilitating Central Asian access to European markets. Cooperation with the European Union, Turkey, China, Georgia, Kazakhstan, and Turkmenistan further enhances the country's logistics position. Azerbaijan has established a comprehensive legal framework through the Law on Transport, Law on Road Transport, Law on Railway Transport, and Law on Sea Ports. Strategic documents, including the 2016 Strategic Roadmap for Logistics and Trade Development and the 2022–2026 State Program for the Development of Logistics and Transit Potential, emphasize infrastructure modernization, transit expansion, tariff optimization, digital logistics, and simplified customs procedures. These measures support an integrated multimodal system combining rail, road, maritime, and air transportation. However, important challenges remain, including limited border-crossing capacity, transportation costs

and transit times, incomplete digital integration, transit security concerns, and competition from alternative international routes.

5. Conclusion & Recommendations

International freight transportation provides Azerbaijan with significant economic, strategic, and regional integration opportunities. The established legal framework, strategic corridors, and modern logistics infrastructure provide a strong foundation for continued development. To strengthen competitiveness, Azerbaijan should modernize border-crossing facilities, expand digital customs and logistics systems, optimize tariffs and transit procedures, improve transport security, and strengthen coordination with regional partners. Continued institutional reforms, investment in multimodal infrastructure, effective risk management, and harmonization of regulatory procedures are essential for maintaining Azerbaijan's position as a competitive international transport and logistics hub. These measures can improve transit efficiency, reduce logistical costs, attract investment, and increase the country's contribution to regional and global trade networks. Greater emphasis should also be placed on harmonizing regulations, improving data exchange among transport operators, strengthening customs cooperation, and developing freight tracking mechanisms. Such measures would enhance route attractiveness, support investment, and enable Azerbaijan to respond more effectively to changing supply-chain patterns.

Keywords: International Freight Transportation, Azerbaijan, Middle Corridor, Transport Law, Logistics, Transit, Multimodal Transportation, Baku–Tbilisi–Kars, North–South Corridor.

Economic Aspects of Safe Working Conditions in Industrial Enterprises

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1. Introduction

Economic development is a major priority for countries; however, rapid growth should not undermine workers' well-being, health, and safe working conditions. Enterprises may sometimes prioritize production, profitability, and cost reduction over occupational safety, particularly where labor supply exceeds demand. Nevertheless, globalization and the development of an international labor market have increased the importance of protecting workers and improving workplace conditions. According to the International Labor Organization (ILO), more than 2.3 million workers die annually from occupational accidents and diseases, while millions more suffer work-related injuries and illnesses. These outcomes generate substantial economic and social costs for enterprises, households, and economies. Occupational safety is therefore not only a social and health concern but also an important economic issue linked to productivity, human capital, employment, and sustainable economic development.

2. Objectives

This study aims to examine the economic aspects of occupational safety and health in industrial enterprises, identify the direct and indirect costs associated with unsafe working conditions, and assess the economic benefits of preventive and ergonomic measures. It also considers the role of regulation, incentives, insurance, and economic evaluation methods in improving workplace safety.

3. Methodology

The study employs a qualitative analytical approach based on an examination of international occupational safety literature and economic assessment methods. Particular attention is given to ILO evidence, cost-based and output-based evaluation approaches, human capital and friction cost methods, and studies examining regulatory and incentive mechanisms. The analysis considers direct costs, indirect costs, productivity losses, compensation payments, employee replacement costs, and potential economic returns from investments in workplace safety and ergonomic improvements.

4. Results

The analysis demonstrates that occupational accidents, injuries, diseases, and fatalities impose considerable economic costs on enterprises and society. The ILO estimates that approximately 4% of global GDP is lost because of occupational injuries and diseases. Unsafe employment is particularly important in agriculture, construction, forestry, fisheries, mining, and other hazardous industries, where workers face greater exposure to dangerous materials, demanding working conditions, and environmental risks. Occupational health problems also affect workers' families through income losses, poverty, educational disruption, and increased household expenditures. From an enterprise perspective, unsafe working conditions generate medical expenses, compensation payments, absenteeism, productivity losses, employee replacement costs, and additional administrative expenditures. Poor occupational health may also contribute to employment discrimination against older workers, individuals with health limitations, and other groups perceived as potentially generating higher labor costs. Economic evaluation can be conducted using cost-based, output-based, or combined approaches. Cost-based assessment should incorporate both direct expenditures and indirect losses associated with occupational diseases and accidents. The human capital approach estimates

productivity losses associated with worker absence or premature loss of working capacity, whereas the friction cost method focuses on the costs incurred while replacing temporarily or permanently absent employees. The latter may produce lower estimates because losses depend on labor-market conditions and the time required to recruit replacement workers. The findings also indicate that legal requirements alone may be insufficient to achieve optimal occupational safety. Regulatory standards, taxation, wage-related incentives, and insurance mechanisms can encourage enterprises to adopt preventive measures. Occupational safety insurance can create incentives for both employers and employees to reduce workplace risks and undertake preventive actions. Importantly, investments in ergonomic improvements should not be considered solely as additional costs. Although safety measures require financial resources and implementation time, they can increase productivity, reduce absenteeism, improve employee health, lower accident-related expenditures, and generate additional enterprise income over the longer term. Consequently, comprehensive economic assessment should consider both the costs of preventive measures and their expected economic returns.

5. Conclusion & Recommendations

The study concludes that safe working conditions represent an investment in human capital rather than merely an additional business cost. Enterprises should systematically evaluate the direct and indirect costs of occupational accidents, diseases, absenteeism, employee replacement, and unsafe working environments. At the same time, the potential productivity and income gains associated with ergonomic improvements should be incorporated into investment decisions. Governments should strengthen occupational safety regulations, improve enforcement, develop appropriate insurance mechanisms, and introduce targeted economic incentives for preventive investment. Enterprises should establish systematic workplace risk assessments, invest in ergonomic technologies and employee training, and monitor safety-related costs and productivity outcomes. Integrating economic evaluation with occupational health policies can improve worker welfare, reduce enterprise costs, increase productivity, and contribute to sustainable and inclusive economic development.

Keywords: Occupational Safety, Working Conditions, Industrial Enterprises, Human Capital, Workplace Health, Economic Costs, Productivity, Ergonomics, Insurance, Sustainable Development.

Willingness to Pay for Electric Public Transport: A Global Literature Review

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1. Introduction

The transition to electric public transport is increasingly recognized as an important strategy for reducing greenhouse gas emissions, improving urban air quality, and promoting sustainable mobility. Although willingness to pay (WTP) for electric public transport has been widely examined internationally, evidence remains fragmented, while Pakistan lacks empirical research to guide electric bus implementation. This study reviews global evidence on WTP and assesses its relevance to Pakistan's urban transport context.

2. Objectives

The study aims to identify key determinants of WTP for electric public transport, examine methodological approaches, identify research gaps, and develop policy and research priorities for transport electrification in Pakistan.

3. Methodology

A systematic literature review was conducted following PRISMA 2020 guidelines. Peer-reviewed quantitative studies published between 2010 and 2025 were identified, screened, and synthesized. The review examined socioeconomic, behavioral, institutional, and service-related determinants of WTP and assessed regional variations. Findings were subsequently contextualized within Pakistan's socioeconomic, institutional, and transport environment.

4. Results

The review identifies income, environmental awareness, fuel-price sensitivity, service quality, gender, age, education, institutional trust, and infrastructure reliability as major WTP determinants. Their effects vary across economic contexts. The literature reveals a substantial absence of Pakistan-specific WTP studies. Affordability constraints, unreliable electricity supply, limited charging infrastructure, low environmental awareness, and institutional trust challenges may significantly influence commuter preferences.

5. Conclusion & Recommendations

International evidence provides useful insights but cannot be directly transferred to Pakistan without contextual validation. Future research should develop Pakistan-specific WTP models. Policymakers should consider affordable and differentiated fares, reliable charging infrastructure, women-friendly services, environmental awareness campaigns, and greater institutional transparency to support sustainable electric public transport.

Keywords: Willingness to Pay (WTP); Electric Public Transport; Electric Buses; Sustainable Urban Mobility; Pakistan; Environmental Sustainability.

Socioeconomic Inequalities and Children's Lifestyle Behaviors in Punjab, Pakistan: Evidence from Household Survey Data

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1. Introduction:

Children's lifestyle behaviors during early life have important implications for their physical health, cognitive development, and long-term well-being. In Pakistan, limited empirical evidence examines children's overall lifestyle using a multidimensional behavioral perspective. This study investigates socioeconomic and demographic factors associated with children's lifestyle behaviors in Faisalabad, Pakistan, using a composite lifestyle index.

2. Objectives:

The study aims to assess the determinants of children's lifestyle behaviors by examining the influence of parental education, household characteristics, child demographics, eating habits, sleeping patterns, physical activity, and screen time.

3. Methodology:

Primary data were collected from 170 households in Faisalabad through a cross-sectional survey using stratified random sampling across different income groups. A composite lifestyle index was developed by integrating physical activity, screen time, eating habits, and sleeping patterns. Multiple linear regression was employed to identify factors significantly associated with children's lifestyle scores.

4. Results:

The regression model explained 73.7% of the variation in lifestyle scores. Parental education ($\beta = 0.109$, $p < 0.001$), sleeping habits ($\beta = 0.201$, $p < 0.001$), and eating habits ($\beta = 0.290$, $p < 0.001$) were positively associated with healthier lifestyles. Conversely, larger household size ($\beta = -0.052$) and excessive screen time ($\beta = -0.141$) negatively influenced lifestyle scores. Parental expenditure and child gender were statistically insignificant.

5. Conclusion & Recommendations:

Children's lifestyle behaviors are influenced more strongly by parental knowledge and behavioral practices than economic resources alone. Policies should promote parental education, healthy eating and sleeping practices, responsible screen use, and digital media literacy to support healthier child development and reduce lifestyle-related inequalities.

Keywords: Children's Lifestyle; Sleeping Habits; Eating Habits; Screen Time; Socioeconomic Status; Parental Education; Pakistan

Microfinance and Women Empowerment in Punjab

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1. Introduction:

Microfinance is widely recognized as a tool for poverty reduction and women's empowerment, particularly in developing economies where women face financial and social constraints. In Pakistan, however, evidence on the broader dimensions of empowerment remains limited. This study examines how microfinance participation contributes to women's economic, psychological, and decision-making empowerment in Punjab.

2. Objectives:

The study aims to assess the contribution of microfinance to women's empowerment, identify key factors influencing empowerment outcomes, and determine the roles of financial literacy and women's control over borrowed funds.

3. Methodology:

Primary data were collected from 96 women microfinance clients in Punjab using a structured questionnaire. The study employed descriptive statistics, Cronbach's alpha, and multiple linear regression to evaluate empowerment outcomes and their determinants. The measurement scale demonstrated high internal consistency ($\alpha = 0.910$). A systematic review of 41 studies from Pakistan, India, and Bangladesh was also used to contextualize the empirical findings.

4. Results:

The findings indicate that financial literacy and effective utilization and control of loans were the strongest empowerment outcomes. Psychological well-being showed moderate improvement, whereas public speaking and personal financial autonomy remained relatively weak. The regression model explained 37.7% of the variation in women's empowerment ($R^2 = 0.377$). Financial literacy ($\beta = 0.273$, $p < 0.01$) and loan control ($\beta = 0.289$, $p < 0.01$) were significant positive predictors of empowerment.

5. Conclusion & Recommendations:

Microfinance can contribute meaningfully to women's empowerment when women possess financial knowledge and autonomy over loan utilization. Policymakers and microfinance institutions should complement credit provision with financial literacy training, greater control over borrowed funds, business skills development, and non-financial support services to strengthen women's economic and personal empowerment.

Keywords: Microfinance; Microcredit; Women's Empowerment; Financial Literacy; Loan Control; South Asia

The Impact of Minimum Wage Levels on Poverty: Cross-Sectional, Panel, and Time-Series Analysis

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1. Introduction

The minimum wage (MW) is an important policy instrument for protecting low-skilled and low-income workers, but its economic effects are multidimensional. Higher minimum wages can increase earnings and improve household welfare, yet they may also raise labor costs, influence employment, affect business competitiveness, and alter aggregate economic outcomes. Governments therefore face the challenge of establishing minimum wage levels that provide adequate social protection without creating excessive pressure on enterprises and labor markets. This study examines the relationship between minimum wage levels, poverty, employment, and economic growth, with particular attention to oil-rich countries where economic activity is strongly influenced by the energy sector.

2. Objectives

The study aims to assess the direct and indirect effects of minimum wage levels on poverty and household welfare. Specifically, it examines whether minimum wage increases contribute to economic growth, influence unemployment, and reduce poverty through employment and income channels. The study also compares countries with and without statutory minimum wage systems and evaluates whether the social protection role of minimum wages is more important than their contribution to macroeconomic growth.

3. Methodology

The study employs cross-sectional, panel, and time-series analytical approaches using international secondary data. Information on employment, poverty, and economic growth was obtained primarily from the World Bank, while minimum wage data were compiled from international statistical sources. A panel dataset covering 97 countries during 2014–2016 was constructed, providing 291 observations. The analysis uses the ratio of minimum wage to GDP per capita (MWS) to assess the relationship between minimum wage levels, GDP per capita growth (GDPPCG), and unemployment (UNEMP). A separate analysis considers 14 oil-rich countries, although minimum wage information was available for only three years. Countries without statutory minimum wages, including Norway, the United Arab Emirates, Qatar, and Venezuela, were retained to provide comparative evidence. The analysis evaluates both direct relationships and potential indirect effects operating through employment and economic growth.

4. Results

The findings indicate that the relationship between minimum wage levels and economic growth varies considerably across countries and development contexts. Panel analysis of 97 countries shows no statistically significant relationship between the minimum wage-to-GDP-per-capita ratio and GDP per capita growth. Although the overall statistical significance of the relationship is acceptable, the explanatory power is very low, suggesting that minimum wage levels do not substantially determine economic growth at the macroeconomic level. Similarly, no statistically significant relationship is identified between MWS and unemployment. These findings provide limited support for the argument that higher minimum wages systematically generate unemployment or reduce aggregate economic performance. Analysis of oil-rich countries further indicates that minimum wage increases do not

substantially reduce poverty through the economic growth channel. This is partly explained by the dominant role of oil and gas sectors, which are relatively less labor-intensive and therefore limit the transmission of minimum wage changes into broader economic growth. Instead, the principal effect of minimum wage policy appears to operate through household incomes and the direct social protection of low-skilled workers.

5. Conclusion and Recommendations

The study concludes that the minimum wage primarily serves a social protection function rather than acting as a powerful instrument for promoting economic growth. The empirical evidence does not establish a strong relationship between minimum wage levels and either GDP growth or unemployment. Nevertheless, appropriate minimum wage increases can improve the living standards of employed low-skilled workers, strengthen household purchasing power, and contribute to reducing income disparities. Policymakers should therefore adopt balanced and evidence-based minimum wage policies that reflect productivity, inflation, living costs, and labor-market conditions. In oil-rich economies, minimum wage policy should be complemented by broader employment, social protection, skills development, and economic diversification measures. Such an integrated approach can strengthen the poverty-reduction impact of wage policy while minimizing potential pressures on employers and labor markets. Regular reviews should ensure that wage adjustments remain consistent with productivity trends and inflation, while targeted support should protect vulnerable workers and encourage formal employment opportunities.

Keywords: Minimum Wage; Poverty; Employment; Economic Growth; Social Protection; Oil-Rich Countries; Unemployment

Women's Participation in Agricultural Value Chains in Pakistan: Barriers, Economic Empowerment, and Inclusive Growth

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1. Introduction:

Women play an important yet frequently undervalued role in Pakistan's agricultural value chains through crop production, livestock management, post-harvest handling, processing, and marketing. Despite their substantial contribution, women's participation remains largely informal and constrained by socioeconomic, institutional, and cultural barriers. This review examines women's participation across agricultural value chains and evaluates its implications for empowerment, household welfare, food security, and inclusive rural development.

2. Objectives:

The study aims to identify major barriers limiting women's participation in agricultural value chains, assess opportunities for economic empowerment, and examine policy interventions that can promote gender-inclusive agricultural transformation in Pakistan.

3. Methodology:

A qualitative review of existing literature, policy documents, government programs, and development interventions was conducted. The evidence was thematically synthesized around women's access to productive resources, finance, technology, extension services, market information, decision-making, and value-chain opportunities. Particular attention was given to interventions promoting women's economic empowerment and inclusive agricultural development.

4. Results:

The review identifies limited land ownership, restricted access to finance, modern technologies, extension services, education, market information, and decision-making authority as major constraints. Sociocultural norms and gender inequalities further restrict women's participation. Evidence indicates that greater integration of women into agricultural value chains can improve household income, food and nutritional security, poverty reduction, and rural resilience. Digital technologies, producer organizations, financial inclusion, and stronger market linkages offer significant opportunities for expanding participation.

5. Conclusion & Recommendations:

Women's empowerment within agricultural value chains is essential for sustainable agricultural transformation and inclusive growth. Gender-responsive policies, improved access to productive resources and finance, digital technologies, capacity building, stronger producer organizations, and effective market linkages should be prioritized to strengthen women's economic participation and decision-making in Pakistan's agri-food sector.

Keywords: Agricultural Production; Agricultural Value Chains; Women's Empowerment; Nutritional Security; Modern Technologies; Inclusive Growth

Sustainable Development of Small and Medium-Sized Enterprises in the Post-Pandemic Period

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1. Introduction

Small and medium-sized enterprises (SMEs) are important contributors to employment, economic growth, innovation, and competitiveness. However, the COVID-19 pandemic severely disrupted SME operations by reducing demand, restricting market access, interrupting supply chains, increasing production costs, and creating serious liquidity constraints. Many enterprises temporarily suspended operations, while others permanently exited the market. The pandemic also accelerated changes in consumer behavior, remote working, e-commerce, and digital business practices. Although SMEs faced considerable challenges before the pandemic, including limited access to international markets, financial constraints, and low competitiveness, these problems intensified during the crisis. In the post-pandemic period, digital transformation, technological innovation, and new business models have therefore become increasingly important for strengthening SME competitiveness and ensuring sustainable development.

2. Objectives

This study aims to examine the major challenges experienced by SMEs during the COVID-19 pandemic and evaluate the factors influencing their sustainable development in the post-pandemic period. It particularly focuses on financial constraints, production costs, employment difficulties, foreign trade disruptions, digital transformation, technological innovation, and government support.

3. Methodology

The study adopts a qualitative analytical approach based on an assessment of SME development during the 2019–2024 period in Azerbaijan. The analysis considers the major economic and operational challenges experienced by SMEs during and after the pandemic, including financial difficulties, liquidity shortages, employment constraints, production and logistics costs, foreign trade disruptions, and market-access limitations. Particular attention is given to government support measures, tax incentives, digital technologies, e-commerce, innovation, and access to finance as mechanisms for strengthening SME resilience and sustainable development.

4. Results

The analysis indicates that the COVID-19 pandemic significantly affected the financial stability, productivity, employment, and market performance of SMEs. Restrictions on movement and city and road closures disrupted logistics and increased transportation and clearance costs. Declining revenues, weak capital turnover, debt obligations, supplier payments, and limited access to finance created substantial cash-flow pressures. SMEs responded through cost reductions, wage adjustments, remote working arrangements, workforce reductions, and increased reliance on bank loans, personal funds, and other financing sources. Foreign trade was also affected by simultaneous supply- and demand-side disruptions, particularly for enterprises dependent on international markets. At the same time, the pandemic accelerated digitalization and encouraged SMEs to adopt online sales, e-commerce platforms, remote working, and innovative technologies. In Azerbaijan, government support programs and tax incentives during and after the pandemic contributed positively to business continuity and recovery. The post-pandemic environment has consequently created opportunities for SMEs to

improve competitiveness through digital transformation, technological innovation, market diversification, and stronger integration into global value chains. However, persistent challenges related to finance, employment, competitiveness, international market access, and regional development continue to constrain long-term sustainability.

5. Conclusion & Recommendations

The study concludes that sustainable SME development in the post-pandemic period requires a combination of financial resilience, technological transformation, innovation, market diversification, and effective government support. Policies should facilitate SMEs' access to global markets, expand affordable financing, promote e-commerce and digital technologies, encourage technological innovation, and strengthen employment opportunities in regions. Continued tax incentives, targeted support programs, digital infrastructure, and skills development can further enhance SME resilience and competitiveness. Strengthening collaboration among government institutions, financial organizations, technology providers, and SMEs is also essential for creating an enabling business environment. These measures can help Azerbaijani SMEs overcome pandemic-related vulnerabilities while contributing to employment generation, innovation, regional economic development, and sustainable national economic growth.

Keywords: Small and Medium-Sized Enterprises, Sustainable Development, COVID-19, Digital Transformation, E-Commerce, Innovation, Government Support, Azerbaijan

Effect of Owners' Financial Capabilities on SME Outcomes: The Role of Financial Resilience and Advice

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1. Introduction:

Financial resilience is increasingly important for small and medium-sized enterprises (SMEs) operating amid economic uncertainty, financial shocks, and market volatility. Owners' financial capabilities can strengthen firms' ability to manage financial challenges, adapt to adverse conditions, and maintain business continuity. However, the role of financial advice in strengthening this relationship remains insufficiently explored. This study examines how owners' financial capabilities contribute to SME financial resilience and whether financial advice strengthens this relationship.

2. Objectives:

The study aims to examine the effect of owners' financial capabilities on financial resilience and determine whether financial advice moderates this relationship among SMEs.

3. Methodology:

A cross-sectional research design was employed using primary data collected through a structured questionnaire from SME owners and managers directly involved in financial decision-making. Descriptive statistics and structural equation modelling were used to examine the direct and moderating relationships among financial capability, financial resilience, and financial advice.

4. Results:

The findings indicate that financial advice has a significant positive effect on financial resilience. The interaction analysis further demonstrates that financial advice significantly strengthens the positive relationship between owners' financial capabilities and financial resilience. The positive interaction effect suggests that SMEs whose owners actively seek and utilize financial advice derive greater resilience benefits from their financial capabilities. Although the financial resilience model was statistically significant, it explained a relatively small proportion of the variance, indicating that additional organizational and contextual factors may influence SME resilience.

5. Conclusion & Recommendations:

Owners' financial capabilities can enhance SME resilience, particularly when supported by effective financial advice. Policymakers, financial institutions, and advisory providers should strengthen financial literacy programs and improve SMEs' access to reliable financial advisory services. These measures can enhance financial decision-making, resilience, business continuity, and sustainable SME growth.

Keywords: Financial Resilience; Financial Capability; Financial Advice; Small and Medium-Sized Enterprises (SMEs); Moderation Effect

SECTION V

5. Emerging Methodologies and Interdisciplinary Approaches

7 Abstracts

Role of Investor Sentiments in Driving Asymmetric Volatility Spillover Between Crypto and Forex Markets in Pakistan.

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1. Introduction:

The growing integration of cryptocurrency and foreign exchange markets has increased interest in their volatility dynamics and behavioral drivers, particularly in emerging economies. This study examines the relationship between Bitcoin (BTC) returns and the Pakistani Rupee–US Dollar (PKR/USD) exchange rate, with particular emphasis on volatility spillovers, asymmetric shocks, and investor sentiment.

2. Objectives:

The study aims to assess volatility persistence and asymmetric effects between cryptocurrency and foreign exchange markets, examine their correlation and portfolio diversification potential, and evaluate the influence of investor behavioral factors on financial risk-taking and market participation.

3. Methodology:

Time-series econometric techniques, including AR(1)-DCC-GARCH, GARCH(1,1), and EGARCH models, were employed to analyze volatility dynamics, conditional correlations, and asymmetric responses. Structural Equation Modeling using SmartPLS 4 was further applied to examine behavioral determinants of investor decisions, including age, gender, and Fear of Missing Out (FOMO).

4. Results:

Both Bitcoin and PKR/USD exhibited significant volatility clustering and persistence, indicating that previous market shocks substantially influence current volatility. The DCC-GARCH results revealed a weak and statistically insignificant correlation between Bitcoin and PKR/USD, suggesting limited direct dependence between the two markets. Portfolio analysis indicated that Bitcoin offers greater potential for diversification than hedging in Pakistan. EGARCH results confirmed asymmetric volatility, with negative shocks exerting stronger effects than positive shocks. SmartPLS findings showed that investor behavioral characteristics significantly influence market participation and risk-taking, while age negatively affected financial risk-taking and participation. Gender and FOMO were statistically insignificant.

5. Conclusion & Recommendations:

The findings demonstrate that volatility persistence, asymmetric shocks, and investor behavior jointly explain financial market dynamics. Investors should consider Bitcoin for portfolio diversification while strengthening risk-management practices. Policymakers should enhance investor awareness, behavioral finance education, and regulatory frameworks to address risks associated with emerging cryptocurrency and foreign exchange markets.

Keywords: Emerging Markets; Volatility Clustering; Portfolio Diversification; Investor Sentiment; Structural Equation Modeling; Financial Market Dynamics

The Economics of Happiness and Subjective Well-Being: Evidence from Faisalabad

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1. Introduction:

Subjective well-being (SWB) has emerged as an important indicator of human welfare beyond conventional measures such as income and gross domestic product. This study examines the economics of happiness in Faisalabad, Pakistan, by exploring how economic, demographic, health, educational, and social factors influence individuals' life satisfaction and emotional well-being. The study recognizes happiness as a multidimensional outcome shaped by both material and non-material conditions.

2. Objectives:

The study aims to identify the socioeconomic and demographic determinants of subjective well-being and assess the relative contributions of income, employment, education, health, family support, social interaction, and community engagement to happiness.

3. Methodology:

Primary data were collected from respondents in Faisalabad using a structured questionnaire. Descriptive statistics were employed to summarize socioeconomic characteristics and well-being indicators, while multiple regression analysis was used to estimate the effects of economic, demographic, and social factors on subjective well-being and life satisfaction.

4. Results:

The findings demonstrate that both economic and non-economic factors significantly contribute to subjective well-being. Income and employment are positively associated with happiness, although their marginal contribution declines at higher income levels. Education and health emerge as important determinants of improved quality of life and life satisfaction. Social factors, particularly family support, interpersonal interaction, and community engagement, also play a substantial role in enhancing emotional well-being. The results indicate that economic prosperity alone cannot fully explain variations in happiness among individuals.

5. Conclusion & Recommendations:

The study concludes that improving subjective well-being requires policies that extend beyond income enhancement and employment generation. Greater investment in education, healthcare, social protection, community participation, and supportive social environments is recommended to promote inclusive welfare and sustainable improvements in happiness in Faisalabad.

Keywords: Economics of Happiness; Subjective Well-Being (SWB); Life Satisfaction; Income; Employment; Education; Health

Adoption of Electric Bikes among Students

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1. Introduction:

Growing environmental concerns, rising fuel prices, traffic congestion, and the need for sustainable mobility have increased interest in electric bikes as an affordable and environmentally friendly transportation option. University students represent an important potential user group because of their regular commuting needs and increasing exposure to sustainable technologies. However, empirical evidence on the factors influencing electric bike adoption among Pakistani students remains limited. This study examines the determinants of students' intention to adopt electric bikes.

2. Objectives:

The study aims to identify the major factors influencing students' intention to adopt electric bikes and assess the roles of affordability, environmental awareness, perceived usefulness, and social influence in adoption decisions.

3. Methodology:

The study employs a quantitative research design based on primary data collected from university students through a structured questionnaire. Information will be gathered regarding students' socioeconomic characteristics, transportation preferences, environmental awareness, perceived usefulness, affordability, social influence, and intention to adopt electric bikes. Appropriate statistical and econometric techniques will be applied to identify significant determinants of adoption intention.

4. Results:

The analysis is expected to demonstrate that environmental awareness, affordability, perceived usefulness, and social influence are important determinants of students' intention to adopt electric bikes. Students who perceive electric bikes as economical, convenient, environmentally beneficial, and socially acceptable are expected to exhibit stronger adoption intentions. High purchase costs and concerns regarding battery performance, charging facilities, and maintenance may nevertheless constrain adoption.

5. Conclusion & Recommendations:

The study is expected to provide evidence for promoting sustainable student mobility in Pakistan. Policymakers should consider student-oriented incentives, affordable financing, charging infrastructure, awareness campaigns, and supportive institutional policies. Universities and manufacturers can further encourage adoption by improving accessibility, affordability, and awareness of electric-bike benefits.

Keywords: Electric Bikes; Students; Technology Adoption; Sustainable Transportation; Environmental Awareness; Pakistan

The Potential of Seaweed-Derived Biochar for Enhancing Oil Palm Productivity: A New Opportunity for Integrating the Blue Economy and Sustainable Agriculture

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1. Introduction

Oil palm productivity is increasingly constrained by declining soil fertility, organic matter depletion, and dependence on chemical fertilizers. Seaweed-derived biochar offers a sustainable amendment that improves soil health, supports carbon sequestration, and reduces biomass waste. Its integration into oil palm systems can strengthen circular resource use and connect Blue Economy initiatives with sustainable agriculture.

2. Objectives

This study evaluates the potential of seaweed-derived biochar to improve oil palm productivity by enhancing soil physicochemical properties, increasing nutrient use efficiency, promoting carbon sequestration, and supporting sustainable agriculture within a Blue Economy framework.

3. Methodology

A qualitative review synthesized peer-reviewed literature, technical reports, and international databases published from 2010 to 2026, focusing on seaweed biochar production, physicochemical properties, nutrient composition, soil fertility, oil palm growth, carbon storage, environmental sustainability, opportunities, and research priorities.

4. Results

The review demonstrates that seaweed-derived biochar enhances soil organic carbon, cation exchange capacity, water retention, microbial activity, and nutrient availability. Its high potassium, calcium, magnesium, and micronutrient contents can partially substitute inorganic fertilizers, reduce production costs while improving crop productivity. Furthermore, biochar supports long-term carbon sequestration, lowers greenhouse gas emissions, and creates additional income opportunities for coastal communities through integrated seaweed cultivation and circular bioeconomy practices.

5. Conclusion & Recommendations

Seaweed-derived biochar offers a sustainable approach to improving oil palm productivity, soil health, and climate resilience. Future research should emphasize long-term field trials, optimized production, life cycle and economic assessments, and quality standards. Collaboration among researchers, policymakers, and industry stakeholders can accelerate adoption and integrate Blue Economy principles into sustainable agriculture.

Keywords: Seaweed biochar; oil palm; Blue Economy; sustainable agriculture; carbon sequestration; soil fertility; circular bioeconomy.

From Agricultural Waste to Nanomedicine: An Interdisciplinary Approach to Green Synthesis of Silver Nanoparticles Using Citrus Peel Extracts

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1. Introduction:

The valorization of agricultural waste through green nanotechnology offers promising opportunities for sustainable healthcare and circular bioeconomy development. Citrus peels are abundant agro-industrial residues containing flavonoids, phenolic compounds, terpenoids, and organic acids that can function as natural reducing and stabilizing agents. This study explores the green synthesis of silver nanoparticles (AgNPs) using aqueous citrus peel extract and evaluates their physicochemical and biological properties.

2. Objectives:

The study aims to synthesize AgNPs using citrus peel extract as an eco-friendly reducing and stabilizing agent, characterize the synthesized nanoparticles, and assess their antibacterial and antioxidant potential.

3. Methodology:

Aqueous citrus peel extract was prepared and mixed with different concentrations of silver nitrate solution. Nanoparticle formation was initially confirmed through a characteristic color change. The synthesized AgNPs were characterized using UV–visible spectroscopy and scanning electron microscopy (SEM). Their antibacterial and antioxidant activities were subsequently evaluated at different nanoparticle concentrations.

4. Results:

The results confirmed successful formation of AgNPs, with UV–visible spectroscopy showing surface plasmon resonance peaks between 410 and 440 nm. SEM analysis revealed predominantly spherical nanoparticles with nanoscale characteristics. The synthesized AgNPs exhibited significant antibacterial and antioxidant activities, with biological effectiveness generally increasing as nanoparticle concentration increased.

5. Conclusion & Recommendations:

Citrus peel waste can serve as an effective, low-cost, and environmentally friendly resource for synthesizing biologically active silver nanoparticles. The findings demonstrate the potential of agricultural waste valorization for sustainable nanomedicine and circular bioeconomy applications. Further studies should evaluate toxicity, stability, and biomedical efficacy under in vivo conditions.

Keywords: Citrus Peels; Silver Nanoparticles; Green Nanotechnology; Agricultural Waste; Antibacterial Activity; Antioxidant Activity; Circular Bioeconomy

Laboratory Bioassay to Evaluate the Toxicity and Feeding Suppression of Simodis 100 DC (Plinazolin) on Cotton Jassid (*Amrasca biguttula biguttula*)

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1. Introduction

Cotton is Pakistan's principal cash crop, yet its productivity is severely constrained by the cotton jassid (*Amrasca biguttula biguttula*), a destructive sap-sucking pest causing hopper burn, leaf curling, chlorosis, and yield losses. Continuous reliance on conventional insecticides has accelerated resistance development and negatively affected beneficial arthropods. Plinazolin (Simodis 100 DC), a novel isoxazoline insecticide with a unique mode of action, offers a promising alternative for sustainable jassid management.

2. Objectives

To evaluate the toxicity of Simodis 100 DC against cotton jassid nymphs and adults, determine lethal concentrations, and assess its feeding suppression and behavioral effects under laboratory conditions.

3. Methodology

Cotton jassids collected from unsprayed fields will be reared for two generations before bioassays. A completely randomized design will compare five concentrations of Simodis 100 DC with an untreated control using the leaf-dip method. Mortality will be recorded after 24, 48, and 72 hours, while probit analysis will estimate LC_{50} and LC_{90} values. Feeding suppression will be quantified through leaf damage assessment and behavioral observations, including reduced movement, feeding cessation, and abnormal posture.

4. Results

The bioassay is expected to demonstrate concentration- and time-dependent increases in mortality, with nymphs likely exhibiting greater susceptibility than adults. Treated insects are anticipated to show significant reductions in feeding activity and visible leaf injury compared with the control.

5. Conclusion & Recommendations

Simodis 100 DC is expected to provide effective toxicity and feeding suppression against cotton jassid, supporting its integration into resistance management and environmentally sustainable integrated pest management (IPM) programs.

Keywords: Cotton jassid, *Amrasca biguttula biguttula*, Plinazolin, Feeding suppression, Insecticide toxicity

Comparative Efficacy and Sublethal Effects of Selected Insecticides Against Wheat Aphids Using Laboratory Bioassays

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1. Introduction:

Wheat is Pakistan's major staple crop, but its productivity is threatened by aphid infestations that reduce plant vigor and may transmit important viral diseases. Heavy reliance on insecticides has contributed to resistance development and adverse effects on beneficial organisms. Moreover, sublethal insecticide effects on aphid development and reproduction remain insufficiently documented.

2. Objectives:

This study aims to compare the toxicity of selected insecticides against wheat aphids under laboratory conditions, determine their time-dependent mortality, and evaluate sublethal effects on aphid development, survival, longevity, and reproduction.

3. Methodology:

Wheat aphids will be collected from major wheat-growing areas of Pakistan and identified to species level. Laboratory colonies will be maintained on pesticide-free wheat seedlings under controlled conditions. Toxicity will be assessed using leaf-dip, residual-contact, and systemic-exposure bioassays. Mortality will be recorded at 24, 48, and 72 hours after treatment. Probit analysis will estimate LC_{50} and LC_{90} values. Aphids exposed to selected sublethal concentrations will subsequently be evaluated for developmental duration, survival, adult longevity, and fecundity.

4. Results:

The study is expected to identify differences in insecticide toxicity and susceptibility among wheat aphid populations. Sublethal exposure is anticipated to alter aphid development, survival, longevity, and reproductive performance, providing additional evidence of insecticide impacts beyond direct mortality.

5. Conclusion & Recommendations:

The findings will provide baseline evidence for selecting effective insecticides while supporting resistance management and conservation of beneficial organisms. Results can guide integrated pest management strategies and promote more sustainable wheat aphid control.

Keywords: Wheat aphids, Insecticide toxicity, Sublethal effects, Laboratory bioassay, LC_{50}

SECTION VI

6. Livestock Economics and Sustainable Animal Systems

2 Abstracts

Evaluating The Role Of Banana Peel, Whole Wheat Flour, And Groundnut In Enhancing Nile Tilapia Performance

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1. Introduction

The increasing cost of conventional aquafeeds, particularly fish meal and commercial concentrates, is a major constraint to sustainable Nile tilapia (*Oreochromis niloticus*) production. Agro-industrial by-products such as banana peel, whole wheat flour, and groundnut meal offer affordable and locally available alternatives with potential nutritional and functional benefits. This study evaluates their combined use as partial substitutes for conventional aquafeeds to improve fish growth, feed utilization, nutritional quality, and water quality.

2. Objectives

The study aimed to assess the effects of different inclusion levels of banana peel flour, whole wheat flour, and groundnut meal on growth performance, survival, feed efficiency, meat proximate composition, and water quality of Nile tilapia.

3. Methodology

A completely randomized design was used with 120 fingerlings averaging 5.3 ± 0.0 g, stocked in 12 aquaria with three replicates per treatment. Four diets were tested: control (T1) and combined agro-by-product blends at 10% (T2), 20% (T3), and 30% (T4) inclusion levels. Fish were fed at 5% body weight twice daily for eight weeks. Growth and feed-utilization parameters were evaluated statistically at the 5% significance level.

4. Results

Treatment T3 (20% inclusion) produced the highest final weight, weight and length gain, specific growth rate, feed utilization efficiency, and protein efficiency ratio ($p < 0.05$). It also resulted in higher crude protein and lipid contents and lower moisture and ash levels in fish flesh. All treatments achieved 100% survival, while water-quality parameters remained within permissible limits.

5. Conclusion & Recommendations

A 20% inclusion level of the combined agro-by-product blend provided the best overall growth, feed efficiency, and fillet nutritional quality. These findings demonstrate the potential of banana peel, wheat flour, and groundnut meal as sustainable, cost-effective alternatives for Nile tilapia aquafeeds.

Keywords: Nile Tilapia; Aquafeed Alternatives; Growth Performance; Agro-industrial By-products; Plant-based Feed

Integrating Moringa Oleifera with Poultry By-Product Meal: A Nutritional Strategy for Enhanced Tilapia Growth and Meat Quality

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1. Introduction

Aquaculture is one of the fastest-growing food-producing sectors and an increasingly important source of high-quality animal protein. However, the high cost and limited sustainability of fish meal remain major constraints to profitable aquaculture production. Poultry by-product meal (PBM) represents an economical alternative protein source, while Moringa oleifera leaves contain bioactive compounds with antioxidant and antimicrobial properties that may improve fish health and nutritional performance. Combining these ingredients may provide a cost-effective and sustainable approach to reducing dependence on conventional fish meal while enhancing fish growth and meat quality.

2. Objectives

This study evaluated the combined effects of Moringa oleifera leaf powder and poultry by-product meal as an alternative protein source on growth performance, feed conversion efficiency, survival, water quality, and meat proximate composition of Nile tilapia (*Oreochromis niloticus*).

3. Methodology

A completely randomized design was used over an eight-week feeding trial. A total of 120 Nile tilapia fingerlings were randomly allocated to four dietary treatments, each comprising three replicates of 10 fish. Following two weeks of acclimatization, fish had an average initial weight of 5.2 g and length of 4.5 cm. The control group (T1) received a basal diet without the combined supplement, whereas experimental groups T2, T3, and T4 received diets containing 20%, 40%, and 60% of the combined M. oleifera and PBM supplement, respectively. Growth, feed conversion ratio (FCR), survival, meat proximate composition, and water-quality parameters were assessed. Treatment means were compared using Tukey's post hoc test at $p < 0.05$.

4. Results

All treatments recorded a 100% survival rate, while water-quality parameters remained within optimal ranges throughout the experiment. The 40% inclusion treatment (T3) produced the best overall performance, with a weight gain of 21.8 ± 1.45 g and length gain of 9.30 ± 1.22 cm. T3 also recorded the lowest FCR (0.82 ± 0.04), compared with 0.90 ± 0.05 at the 60% inclusion level. The highest meat proximate composition was also observed at the 40% inclusion level. Significant differences among treatments were observed for the measured growth, feed utilization, and meat-quality parameters ($p < 0.05$).

5. Conclusion & Recommendations

The combined inclusion of M. oleifera leaf powder and PBM at 40% produced the most favorable growth performance, feed conversion, survival, and meat quality in Nile tilapia. The findings demonstrate that a 40% inclusion level can serve as an affordable and sustainable alternative to conventional fish meal. Further studies should evaluate long-term performance, economic returns, and optimal ingredient ratios under commercial farming conditions.

Keywords: Sustainable Aquafeed; Moringa oleifera; Poultry By-Product Meal; Natural Antioxidant; Alternative Protein Source; Eco-friendly Aquaculture

SECTION VII

7. Food Sciences and Nutrition Systems

10 Abstracts

Desirability-Based Optimization of Nutritionally Enhanced and Rheologically Modified Herbal Wheat Bread

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1. Introduction

Growing concerns regarding micronutrient deficiencies and non-communicable diseases have increased interest in functional foods and traditional medicinal herbs. Pakistan possesses diverse culinary herbs, including garlic, ginger, turmeric, fenugreek, cumin, nigella, fennel, and coriander, with considerable nutritional and bioactive potential. Wheat bread, as a widely consumed staple, provides an effective vehicle for incorporating these functional ingredients.

2. Objectives

This study aimed to develop herb-enriched wheat bread and evaluate the effects of different herb combinations on nutritional composition, dough rheology, sensory characteristics, and overall product desirability.

3. Methodology

Wheat flour was supplemented with selected herbal combinations, and formulations were evaluated for proximate composition, mineral content, farinographic and extensographic properties, and sensory characteristics. A single-factor factorial design and desirability-function approach were employed to identify the optimum formulation based on nutritional and functional attributes.

4. Results

Herbal supplementation significantly improved nutritional characteristics. Cumin–nigella blends showed the highest crude fat content ($2.137 \pm 0.070\%$), while ajwain–nigella blends recorded higher protein content ($11.812 \pm 0.31\%$). Selected formulations increased calcium (881.36 ± 7.28 ppm), iron (2.150 ± 0.089 ppm), and zinc (0.676 ± 0.020 ppm). Cumin–fennel blends demonstrated increased dough energy (61.00 ± 1.0 cm²) and resistance to extension (284.00 ± 3.61 BU), whereas nigella–coriander blends showed the highest water absorption ($58.77 \pm 0.67\%$) and dough development time (5.53 ± 0.12 min). Sensory attributes varied among formulations. The B+D combination achieved the highest predicted desirability value (0.718).

5. Conclusion & Recommendations

Herbal enrichment improved the nutritional and rheological properties of wheat bread, with B+D identified as the most desirable formulation. Herb-infused bread offers promising potential as a functional food for improving dietary quality and supporting healthier food choices.

Keywords: Functional Bread; Black Cumin; Coriander; Ginger; Medicinal Plants; Desirability Function Approach

Strengthening Food and Nutrition Security through Nutrition-Sensitive Agriculture and Food Fortification: A Dual Approach to Combat Malnutrition

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1. Introduction

Malnutrition remains a major global public health challenge, with more than two billion people affected by undernutrition and micronutrient deficiencies, commonly referred to as “hidden hunger.” Despite improvements in agricultural productivity, inadequate dietary diversity and nutrient intake persist, particularly in low- and middle-income countries. Nutrition-sensitive agriculture (NSA) and food fortification offer complementary pathways to address these challenges by improving dietary quality and correcting micronutrient deficiencies.

2. Objectives

This study synthesizes evidence on NSA and food fortification as complementary strategies for improving food and nutrition security and reducing malnutrition, particularly micronutrient deficiencies among vulnerable populations.

3. Methodology

A narrative review of recent scientific literature was conducted, focusing on nutrition-sensitive agricultural interventions, crop diversification, biofortification, and large-scale food fortification programs. Evidence was critically synthesized to assess their effects on dietary diversity, micronutrient intake, affordability, and food and nutrition security, with particular emphasis on the potential benefits of integrating agriculture- and fortification-based interventions.

4. Results

The reviewed evidence indicates that NSA can improve household dietary diversity, micronutrient intake, and food access through diversified production and biofortified crops. However, agriculture-based interventions alone may not adequately address widespread micronutrient deficiencies. Food fortification has demonstrated substantial effectiveness in reducing iron, vitamin A, and iodine deficiencies and represents a cost-effective population-level intervention. Evidence further suggests that combining agricultural diversification, biofortification, and food fortification can generate stronger and more sustainable nutritional outcomes than implementing individual interventions separately.

5. Conclusion & Recommendations

Integrating NSA with food fortification provides a comprehensive strategy for improving food and nutrition security and reducing malnutrition. Policymakers should promote coordinated food-system interventions linking agricultural production, dietary diversification, biofortification, and fortified staple foods to achieve sustainable nutritional improvements.

Keywords: Food Fortification; Nutrition Security; Nutrition-Sensitive Agriculture; Biofortification; Malnutrition; Public Health

Bridging the Gender Gap in Food Science: A Climate-Equity Approach to Food Safety and Nutrition Security in Agri-Food Systems

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1. Introduction

Food science plays a critical role in addressing global challenges related to food safety, nutrition security, and sustainable agri-food systems. Although women are extensively involved in agricultural production, food preparation, household nutrition, and food-related decision-making, they remain underrepresented in food science research, policy development, and institutional leadership. Persistent structural, institutional, and socio-cultural inequalities limit women's opportunities to contribute fully to food-system innovation and climate-responsive solutions.

2. Objectives

This study examines gender disparities in food science, identifies structural, institutional, and socio-cultural barriers affecting women's participation and leadership, and proposes strategies to advance gender equity within climate-resilient agri-food systems.

3. Methodology

A systematic literature review and analytical framework were employed to examine relevant research, policy documents, and case studies addressing gender representation in food science, food safety, nutrition, and agri-food innovation. Identified barriers were thematically categorized into structural, institutional, and socio-cultural dimensions to assess their implications for women's participation, visibility, and leadership.

4. Results

The findings indicate that women's underrepresentation in food science limits knowledge diversity, innovation, and the effectiveness of nutrition-sensitive interventions. Major barriers include unequal access to research resources, limited mentoring and professional networks, gender-biased institutional practices, restricted leadership opportunities, and inadequate gender-responsive curricula. These constraints are further intensified by climate-related challenges affecting food and nutrition security.

5. Conclusion & Recommendations

Bridging the gender gap requires gender-responsive curricula, equitable resource allocation, structured mentoring, supportive institutional policies, and inclusive leadership pathways. Strengthening women's participation in food science is essential for developing innovative, climate-resilient, inclusive, and nutritionally secure agri-food systems.

Keywords: Gender Equity; Food Science; Nutrition Security; Agri-Food Systems; Climate Innovation; Food Safety

The Impact of Economic Stability on Nutritional and Health Status of the Population

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1. Introduction

Economic stability is an important determinant of population health because it influences income, food affordability, dietary choices, healthcare access, and living conditions. Despite global efforts to improve nutrition, substantial disparities in undernutrition, micronutrient deficiencies, overweight, and obesity persist across income groups. Economic instability, characterized by poverty, unemployment, inflation, food insecurity, and inadequate housing and sanitation, can substantially worsen nutritional outcomes. Rising food prices may encourage households to substitute nutrient-rich foods with cheaper alternatives, while unemployment and low incomes can restrict access to healthcare and adequate diets. Children, pregnant women, and older adults are particularly vulnerable to these effects. This study examines the relationship between economic stability and population nutritional and health outcomes.

2. Objectives

The study aims to assess how income, inflation, poverty, employment, food security, and economic conditions influence nutritional status and health outcomes and to identify policy measures that can reduce nutrition-related inequalities.

3. Methodology

A narrative review of relevant literature, reports, and empirical evidence was conducted to examine the pathways linking economic conditions with food security, dietary quality, nutritional deficiencies, obesity, and healthcare access. Evidence across different income groups and socioeconomic contexts was comparatively assessed.

4. Results

The evidence indicates that economic stability generally improves food affordability, dietary diversity, healthcare access, and nutritional well-being. Conversely, poverty, unemployment, and inflation increase the risks of undernutrition and micronutrient deficiencies. Economic prosperity may also increase consumption of processed foods, contributing to overweight, obesity, and diet-related chronic diseases.

5. Conclusion & Recommendations

Economic stability is fundamental to improving population nutrition and health. Policies should strengthen employment, control food-price volatility, improve social protection, promote affordable nutritious foods, and expand access to healthcare to reduce nutrition-related inequalities.

Keywords: Unemployment; Malnutrition; Public Health; Economic Instability; Food Security; Micronutrient Deficiencies

Comparative Economic Burden of HIV/AIDS on Key Populations and General PLHIV Households IN Faisalabad

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1. Introduction

HIV/AIDS imposes substantial economic and social costs on affected households, particularly in settings where access to affordable healthcare and social protection remains limited. However, evidence comparing the household-level economic burden among key populations (KP) and general people living with HIV (PLHIV) in Pakistan is limited. This study assesses the direct and indirect economic burden of HIV/AIDS and compares the burden between KP and general PLHIV households in Faisalabad.

2. Objectives

The study aims to estimate the annual direct and indirect economic costs of HIV/AIDS among PLHIV households and determine whether the economic burden differs significantly between KP and general PLHIV households.

3. Methodology

A quantitative cross-sectional study was conducted among 110 PLHIV, comprising 55 KP and 55 general PLHIV, registered at HIV treatment centers and community-based organizations in Faisalabad. Face-to-face interviews were conducted using a pre-tested WHO household health expenditure module with a 12-month recall period. Direct medical, direct non-medical, and indirect costs were estimated. Data were analyzed using descriptive statistics, the Mann–Whitney U test, and multiple linear regression in IBM SPSS Version 25.

4. Results

The mean annual economic burden per household was PKR 123,365 (SD = 65,234), with direct costs accounting for approximately 83–84% of total costs. The burden was higher among general PLHIV households (PKR 140,300) than KP households (PKR 106,431), although the difference was statistically insignificant ($p = 0.092$). Opportunistic infection treatment, antiretroviral therapy medicines, and hospital admission costs were significant predictors ($p < 0.001$), with the model explaining 47.7% of variation in total economic burden.

5. Conclusion & Recommendations

HIV/AIDS imposes a substantial economic burden on PLHIV households in Faisalabad. Strengthening financial protection, expanding free healthcare services, and addressing structural barriers affecting KP are essential to reduce household vulnerability and improve equitable access to care.

Keywords: HIV/AIDS; Economic Burden; Key Populations; PLHIV; Household Health Expenditure; Financial Protection

Moringa Oleifera: The Miracle Tree and Its Nutritional, Medicinal, and Agronomic Potential

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1. Introduction:

Moringa oleifera Lam., commonly known as the “Miracle Tree” or “Tree of Life,” is a fast-growing, drought-tolerant plant with substantial nutritional, medicinal, and agricultural potential. Its leaves are rich in protein, essential amino acids, vitamins, minerals, antioxidants, and bioactive compounds, making moringa a promising resource for addressing malnutrition and supporting nutraceutical applications. Bioactive constituents, including polyphenols and isothiocyanates, have been associated with antioxidant, anti-inflammatory, antimicrobial, antidiabetic, and other therapeutic properties. In agriculture, Moringa Leaf Extract (MLE), containing natural plant growth-promoting compounds, has emerged as an economical and environmentally friendly biostimulant for improving crop growth and stress tolerance.

2. Objectives:

This study aimed to highlight the nutritional, medicinal, and agronomic potential of M. oleifera and evaluate the effects of MLE and potassium sulfate on drought-stressed chickpea.

3. Methodology:

A field trial was conducted at the Arid Zone Research Centre, Dera Ismail Khan, using Kabuli chickpea under drought conditions. Foliar applications of MLE and potassium sulfate were evaluated for their effects on growth and yield-related traits.

4. Results:

MLE application improved root and shoot biomass, indicating enhanced vegetative growth under drought stress. Potassium sulfate increased pods per plant and grain yield. Combined application demonstrated complementary benefits, suggesting potential for improving chickpea productivity under water-limited conditions.

5. Conclusion & Recommendations:

M. oleifera represents a multipurpose resource linking human nutrition, healthcare, and climate-resilient agriculture. MLE, particularly when integrated with potassium nutrition, offers a promising, low-cost strategy for improving crop performance under drought conditions.

Keywords: Moringa oleifera, Nutraceutical Potential, Phytochemistry, Biostimulant, Drought Stress

Nutripreneurship as a Pathway to Transform Nutrition Challenges into Sustainable Opportunities in Pakistan

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1. Introduction:

Pakistan faces persistent challenges of malnutrition, micronutrient deficiencies, unhealthy diets, and diet-related non-communicable diseases, with implications for public health, agricultural sustainability, and economic development. Nutripreneurship offers a promising pathway for transforming these challenges into sustainable economic and nutritional opportunities by linking agriculture, food processing, nutrition, and entrepreneurship. Value addition of locally available grains, legumes, nuts, fruits, and vegetables into affordable cereals, beverages, snacks, functional foods, and other nutritious products can improve dietary diversity, reduce post-harvest losses, and strengthen food system efficiency.

2. Objectives:

This study aims to examine the potential of nutripreneurship to improve food and nutrition security, promote value addition of agricultural products, create employment, and strengthen sustainable livelihoods in Pakistan.

3. Methodology:

A narrative review of relevant literature, policy documents, and evidence on food and nutrition security, agricultural value addition, entrepreneurship, and sustainable food systems was conducted. The evidence was synthesized to identify opportunities for developing nutrition-sensitive enterprises and inclusive nutripreneurial models.

4. Results:

The review indicates that nutripreneurship can simultaneously address nutritional deficiencies, reduce food losses, generate employment, and improve rural incomes. Integrating local agro-biodiversity with food processing and market development can expand access to affordable, nutritious, and functional foods. Youth, women, and smallholder farmers can particularly benefit from entrepreneurship training, technical skills, financial services, and improved market linkages.

5. Conclusion & Recommendations:

Nutripreneurship can transform Pakistan's nutrition challenges into sustainable opportunities. Policies should promote nutrition-sensitive enterprises, value addition, entrepreneurship training, investment, and market linkages to build healthier, inclusive, and resilient food systems.

Keywords: Malnutrition, Nutripreneurship, Food and Nutrition Security, Agro-biodiversity, Value Addition

Phytochemical Characterization and Functional Food Potential analysis of Peppermint

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1. Introduction:

Peppermint (*Mentha piperita*) is an important culinary and medicinal herb with considerable potential for functional food applications because of its diverse phytochemical composition and health-promoting properties. This study characterized the phytochemical constituents of peppermint methanolic extract and evaluated its antioxidant and antibacterial activities to assess its functional food potential.

2. Objectives:

The study aimed to identify major phytochemical constituents of peppermint extract and evaluate its antioxidant and antibacterial properties for potential functional food applications.

3. Methodology:

Peppermint methanolic extract was prepared using a soaking method. Preliminary phytochemical screening was conducted to identify major phytochemical groups, while gas chromatography–mass spectrometry (GC–MS) was used to characterize specific bioactive compounds. Total phenolic content (TPC), DPPH radical-scavenging activity, and antibacterial assays were performed to evaluate functional properties.

4. Results:

Phytochemical screening identified terpenoids, steroids, flavonoids, polyphenols, tannins, and glycosides as major constituents. GC–MS analysis identified β -sitosterol (45.886%), p-isopropenyl toluene (16.153%), and 9,12,15-octadecatrien-1-ol (12.099%) as prominent compounds. The extract demonstrated notable antioxidant activity through DPPH radical scavenging and exhibited antibacterial activity against the tested bacterial strains.

5. Conclusion & Recommendations:

The findings demonstrate that peppermint contains diverse bioactive compounds with promising antioxidant and antibacterial properties. Its phytochemical richness supports its potential development as a functional food ingredient. Further studies should evaluate formulation, safety, bioavailability, and clinical efficacy before commercial application.

Keywords: Peppermint, Antioxidant, GC–MS, Antibacterial Activities, DPPH

Zoonotic Parasites in the Food Chain: Bridging Animal Health Research and Food Safety in Sustainable Aquaculture

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1. Introduction:

The rapid expansion of aquaculture is increasing the supply of fish for human consumption while raising concerns about zoonotic parasitic contamination within aquatic food systems. Protozoan and helminth parasites can infect farmed and wild fish, potentially affecting animal health and food safety, particularly where fish are consumed raw or inadequately processed. Integrating animal health with food safety is therefore essential for protecting public health and promoting sustainable aquaculture.

2. Objectives:

This study aims to review the prevalence and transmission pathways of zoonotic parasites in aquaculture, assess associated risks to fish and consumers, and identify surveillance and research priorities linking animal health with food safety governance.

3. Methodology:

A narrative synthesis of literature on veterinary parasitology, aquaculture, and food safety was conducted. Evidence was examined regarding parasite occurrence in farmed and wild fish, contamination during harvesting, evisceration, handling and processing, and the diagnostic and risk-management approaches used throughout the aquaculture-to-consumer chain.

4. Results:

The literature indicates that zoonotic protozoan and helminth parasites occur in edible fish from aquaculture and capture fisheries. Their occurrence and contamination risks are influenced by production intensity, water quality, environmental conditions, and post-harvest handling. Molecular diagnostic techniques have improved detection sensitivity; however, evidence on fish-to-human transmission remains limited, while surveillance and regulatory integration vary substantially across regions.

5. Conclusion & Recommendations:

Zoonotic parasite management should be integrated into food safety policies throughout the aquaculture production-to-consumption chain. Strengthened surveillance, improved processing practices, advanced diagnostics, and coordinated One Health approaches are recommended to protect consumers while supporting sustainable aquaculture development.

Keywords: Zoonotic Parasites, Aquaculture, Food Safety, Animal Health, One Health, Sustainable Fisheries

Feathered Gains: How Lysozyme Optimizes Health and Growth in Japanese Quails (*Coturnix japonica*)

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1. Introduction:

Lysozyme is a naturally occurring antimicrobial enzyme with potential to replace antibiotic growth promoters in poultry production. However, its effectiveness in Japanese quails through different delivery forms remains insufficiently investigated. This study evaluates the effects of lysozyme supplementation on growth performance, hematological characteristics, and serum biochemical parameters.

2. Objectives:

The study aimed to assess the effects of 0.3% lysozyme administered through mash feed, pelleted feed, and drinking water on growth, hematological health, and serum biochemical responses in Japanese quails.

3. Methodology:

Twenty-four healthy male Japanese quails, four weeks old, were randomly assigned to four equal groups (n=6). G1 served as the control, while G2, G3, and G4 received 0.3% lysozyme through mash feed, pelleted feed, and drinking water, respectively. Birds were maintained under uniform conditions. Weekly body weight and feed intake were recorded, while hematological and serum biochemical parameters were evaluated following treatment.

4. Results:

Lysozyme supplementation significantly ($P<0.05$) improved weight gain and feed conversion ratio compared with the control. Erythrocyte count, packed cell volume, hemoglobin, clotting time, and total and differential leukocyte counts increased, with the strongest responses observed in the pelleted-feed group. Serum total protein, albumin, globulin, and albumin-to-globulin ratio increased significantly, whereas glucose, cholesterol, and urea concentrations decreased.

5. Conclusion & Recommendations:

Lysozyme supplementation, particularly through pelleted feed, enhances growth performance, hematological health, and protein metabolism in Japanese quails. It is recommended as a promising natural feed additive for improving poultry health and productivity while reducing dependence on antibiotic growth promoters.

Keywords: Lysozyme, Growth, Hematochemistry, Japanese Quails, Feed Additive

SECTION VIII

8. Agricultural Engineering and Smart Systems

7 Abstracts

Development of an AI-Powered UAV System for Weed Detection

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1. Introduction:

Efficient crop management is essential for improving agricultural productivity, reducing production costs, and ensuring sustainable resource use. Conventional weed detection and irrigation monitoring methods are labor-intensive, time-consuming, and often inefficient across large agricultural fields. Advances in unmanned aerial vehicle (UAV) technology, artificial intelligence (AI), computer vision, and deep learning provide opportunities for automated and real-time crop monitoring. This study develops an AI-powered UAV system for detecting weeds and monitoring irrigated areas in major crops, including wheat, rice, cotton, and maize.

2. Objectives:

The study aims to develop a drone-based intelligent system for real-time weed detection and irrigated-area monitoring and to assess its potential for supporting precision agriculture and efficient farm management.

3. Methodology:

A quadcopter UAV equipped with an RTSP-capable camera was used to capture live video from agricultural fields. Video streams were transmitted through the Real-Time Streaming Protocol (RTSP) and analyzed using image processing, computer vision, machine learning, and deep learning techniques. Crop and weed image datasets were utilized to train and evaluate weed detection models, while aerial recordings were analyzed to identify irrigated areas.

4. Results:

The proposed system enables automated identification of weed-infested areas and monitoring of irrigated portions of agricultural fields. Real-time aerial imaging provides farmers with timely information for targeted weed management and irrigation planning. The system has potential to reduce labor requirements, optimize herbicide application, improve water-use efficiency, and support precision crop management.

5. Conclusion & Recommendations:

The AI-powered UAV system provides a promising approach for automated field monitoring and precision agriculture. Further development should focus on improving model accuracy, expanding crop-specific datasets, and integrating real-time decision-support tools for large-scale agricultural applications.

Keywords: Precision Agriculture, UAV, Weed Detection, Irrigation Monitoring, RTSP Camera, Computer Vision, Deep Learning

Smart Irrigation for Sustainable Agriculture: Assessing the Energy and Economic Benefits of Modern Water-Saving Techniques

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1. Introduction:

Water and energy scarcity are major constraints to sustainable agricultural production, particularly in regions where groundwater pumping is essential for irrigation. Agriculture accounts for a substantial share of global freshwater use, while inefficient irrigation practices increase water losses and energy consumption. Pakistan faces increasing pressure to enhance crop productivity while conserving scarce water and energy resources. Smart irrigation and precision land-management technologies can improve resource-use efficiency and reduce production costs. This study evaluates the energy-saving and economic benefits of Precision Laser Land Levelling (PLL) and bed planting as water-saving technologies for sustainable crop production.

2. Objectives:

The study aims to assess the effects of PLL and bed planting on irrigation-related energy consumption and evaluate their potential economic benefits for farmers.

3. Methodology:

The study examined tube-well irrigation with a discharge capacity of one cusec under conventional and improved field-management practices. Energy requirements for groundwater pumping were compared between traditional unlevelled fields, precision laser-land-levelled fields, and bed-planted fields. Water-use efficiency, energy savings, and associated economic benefits were assessed to determine the effectiveness of modern irrigation practices.

4. Results:

The findings demonstrate substantial energy savings through precision water-management technologies. Precision Laser Land Levelling reduced pumping energy requirements by approximately 33% compared with traditional unlevelled fields, while bed planting achieved an energy reduction of approximately 50%. Reduced pumping requirements resulted in lower irrigation costs and improved economic returns, while simultaneously promoting more efficient utilization of groundwater resources.

5. Conclusion & Recommendations:

PLL and bed planting offer economically viable approaches for reducing irrigation energy consumption and conserving water. Their wider adoption should be supported through farmer training, extension services, technology access, and appropriate policy incentives to promote sustainable and resource-efficient agriculture.

Keywords: Smart Agriculture, Energy Conservation, Irrigation Efficiency, Water-Saving Technologies, Precision Land Levelling, Bed Planting]

From Waste to Water: Repurposed Plastic Bottles as Subsurface Drip Emitters for Efficient Chilli Irrigation"

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1. Introduction:

Water scarcity and the high cost of commercial drip irrigation systems constrain efficient water management among smallholder farmers. Conventional surface irrigation often results in substantial water losses and uneven soil moisture distribution. This study evaluates bottled drip irrigation (BDI), a low-cost subsurface irrigation technique that repurposes waste plastic bottles as localized water emitters for chilli production.

2. Objectives:

The study aims to evaluate the agronomic performance, water-saving potential, water-use efficiency, and economic feasibility of BDI compared with conventional surface irrigation for chilli cultivation.

3. Methodology:

A 130-day field experiment was conducted on sandy loam soil using 1-L repurposed PET bottles perforated with ten 1.2-mm holes and buried 10–15 cm deep near chilli plants. BDI was compared with conventional surface irrigation in replicated 3 × 4 m plots with 45 × 60 cm plant spacing. Soil moisture, plant growth, flowering, yield, water consumption, water-use efficiency, and irrigation costs were evaluated.

4. Results:

BDI maintained more stable root-zone moisture (18–24%) than conventional irrigation (12–32%). Plants under BDI achieved greater height (54.3 ± 3.1 cm), stem diameter (9.8 mm), and earlier flowering (42 days). Fruit yield reached 412 ± 38 g plant⁻¹, representing a 30.8% increase over the control. Seasonal water use declined by 42.8%, from 82.6 to 47.2 L plant⁻¹, while water-use efficiency increased from 3.81 to 8.73 g L⁻¹.

5. Conclusion & Recommendations:

BDI substantially improves chilli productivity and water-use efficiency while reducing irrigation costs. Repurposing waste bottles provides an affordable and environmentally beneficial irrigation option for resource-constrained farmers. Farmer training and field demonstrations are recommended to promote wider adoption in water-scarce regions.

Keywords: Drip Irrigation, Smart Farming, Chilli, Water Saving, Water-Use Efficiency, Plastic Waste

Development and Field Evaluation of a Low-Cost Precision Seed-cum-Fertilizer Drill for Smallholder Wheat Farms in Punjab, Pakistan

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1. Introduction:

Farm mechanization in Pakistan remains concentrated on primary tillage and harvesting, while precision seeding and fertilizer placement technologies remain largely inaccessible to smallholder farmers. Conventional fixed-rate machinery can result in uneven seed distribution, inefficient fertilizer application, higher input costs, and reduced productivity. Low-cost precision technologies adapted to locally available tractors and implements can improve resource-use efficiency and support sustainable wheat production.

2. Objectives:

The study aims to develop and field-evaluate a low-cost, IoT-enabled variable-rate seed-cum-fertilizer drill suitable for smallholder wheat farms and assess its effects on input efficiency, crop establishment, productivity, and farm profitability.

3. Methodology:

A modular prototype was developed for compact and walking tractors using electrical-conductivity and water-activity sensors, GPS, and electronically controlled seed and fertilizer metering mechanisms. Field-specific prescription maps were generated using soil sampling and satellite-derived vegetation indices. The prototype was evaluated over two consecutive wheat seasons using a randomized complete block design with four replications. Seed placement uniformity, fertilizer distribution, germination, stand establishment, grain yield, and input savings were compared with conventional blanket application.

4. Results:

The variable-rate application system improved seed placement uniformity, reduced fertilizer application, and enhanced grain yield and net farm income compared with conventional practices. The modular retrofit design reduced equipment costs and increased compatibility with existing machinery-sharing and custom-hiring systems. However, sensor costs, operator training requirements, and limited rural connectivity remained important adoption constraints.

5. Conclusion & Recommendations:

The low-cost precision drill provides a promising pathway for integrating variable-rate technology into smallholder farming systems. Public-private partnerships, targeted equipment subsidies, farmer training, and machinery-sharing services could accelerate adoption and support resource-efficient, climate-resilient wheat production in Pakistan.

Keywords: Precision Agriculture, Variable-Rate Technology, Farm Mechanization, Seed-cum-Fertilizer Drill, Smallholder Farms, Wheat Production

Smart Irrigation Systems for Water-Saving and Climate-Resilient Farming: Integrating IoT and Precision Technologies in Pakistan

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1. Introduction:

Agriculture accounts for more than 90% of freshwater consumption in Pakistan, while conventional flood and furrow irrigation practices contribute to substantial water losses. Rising temperatures, irregular rainfall patterns, and declining groundwater availability further threaten agricultural sustainability. Smart irrigation systems integrating Internet of Things (IoT) sensors, automation, and precision irrigation technologies can improve water-use efficiency and strengthen climate resilience. This study presents an IoT-based smart irrigation framework designed to optimize irrigation scheduling according to real-time soil and crop conditions.

2. Objectives:

The study aims to develop and evaluate an automated irrigation system that improves water-use efficiency, reduces unnecessary irrigation, and supports climate-resilient crop production through real-time monitoring and precision water management.

3. Methodology:

The proposed system integrates soil moisture and temperature sensors, weather forecasting data, automated solenoid valves, and drip or sprinkler irrigation systems. Irrigation requirements are calculated according to crop growth stage, crop coefficients, and reference evapotranspiration. A mobile application enables farmers to remotely monitor field conditions, receive irrigation alerts, and review irrigation histories. The system was field-tested over multiple operational cycles and compared with conventional irrigation practices.

4. Results:

Field evaluation demonstrated substantial reductions in water and resource use compared with conventional irrigation without compromising crop output. Automated irrigation improved the timing and precision of water application while reducing manual intervention. Real-time monitoring enhanced irrigation decision-making, and the system demonstrated potential for operation on smallholder farms with limited access to reliable electricity.

5. Conclusion & Recommendations:

IoT-enabled smart irrigation provides a cost-effective and scalable approach for improving water-use efficiency and climate resilience in Pakistan. Policy support, farmer training, affordable technologies, and effective technology-transfer mechanisms are recommended to facilitate wider adoption across diverse agro-climatic regions.

Keywords: Smart Irrigation, IoT Sensors, Water-Use Efficiency, Precision Agriculture, Smart Farming, Climate Resilience

Potato Leaf Disease Detection Using a Hybrid YOLO Efficient Net Model Based on Texture Analysis Using GLCM.

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1. Introduction:

Potato is an important food crop worldwide, but its productivity is significantly affected by foliar diseases, particularly early blight (*Alternaria solani*) and late blight (*Phytophthora infestans*). Conventional visual disease diagnosis is labor-intensive, subjective, and difficult to implement across large agricultural fields. Artificial intelligence and computer vision offer opportunities for rapid and automated disease identification. This study proposes a hybrid deep learning approach integrating YOLOv8, EfficientNet-B0, and Gray Level Co-occurrence Matrix (GLCM) texture analysis for automated potato leaf disease detection.

2. Objectives:

The study aims to develop and evaluate a hybrid model for classifying potato leaves as healthy, early blight, or late blight using deep visual and texture-based features.

3. Methodology:

A dataset of 3,000 balanced images from the PlantVillage dataset was used for model development and evaluation. YOLOv8 was employed to detect and extract the leaf region of interest, reducing background interference. EfficientNet-B0 extracted deep visual features, while GLCM generated complementary texture descriptors, including contrast, correlation, energy, and homogeneity. These features were fused for final disease classification and compared with established deep learning models.

4. Results:

The proposed hybrid model achieved 91.17% validation accuracy, with macro-averaged precision, recall, and F1-score of approximately 91.33%. Its performance exceeded VGG16 (82.33%), ResNet50 (85.67%), InceptionV3 (87.17%), and the EfficientNet-B0 baseline (88.50%). YOLOv8 preprocessing improved accuracy by 2.1 percentage points, while GLCM feature fusion produced an additional 2.67 percentage-point improvement.

5. Conclusion & Recommendations:

The YOLOv8-EfficientNet-B0-GLCM framework provides an effective approach for automated potato leaf disease detection. Its integration of spatial, deep visual, and texture features demonstrates strong potential for precision agriculture. Future research should validate the model using field-based images under diverse environmental conditions.

Keywords: Potato Leaf Disease Detection, YOLOv8, EfficientNet-B0, GLCM, Feature Fusion, Precision Agriculture

Impact of Heat Waves on Human Health and Nutrition Status in Punjab Pakistan

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1. Introduction:

Climate change and increasing extreme temperatures pose growing risks to human health and nutritional well-being, particularly in climate-vulnerable regions. In Pakistan, prolonged heat waves during June and July frequently affect Punjab, Sindh, and Balochistan, increasing the risk of heat-related illness and disrupting household well-being. This study investigates the effects of heat waves on human health and nutrition and examines household adaptation and coping responses in Southern Punjab.

2. Objectives:

The study aimed to assess the impacts of heat waves on household health and nutrition, identify socioeconomic factors influencing adaptation, and examine whether greater adoption of coping strategies reduces heat-related health impacts.

3. Methodology:

A cross-sectional survey was conducted among 150 households in District Muzaffargarh, Southern Punjab, characterized by prolonged hot summers and arid climatic conditions. Primary data were collected through a structured questionnaire covering socioeconomic characteristics, heat-wave perceptions, health and nutritional impacts, awareness, and adaptation strategies. Age, income, education, awareness, and adaptation were considered key explanatory factors. Propensity Score Matching was employed to estimate differences in heat-wave impacts between households with higher and lower adaptation levels.

4. Results:

The findings indicate that heat waves substantially affect household health and nutritional well-being. Younger, more educated, and higher-income respondents were more likely to adopt coping and adaptation strategies. Households implementing greater numbers of adaptation measures experienced comparatively lower health impacts than those with limited adaptation. Education, income, and awareness appeared to strengthen households' capacity to respond effectively to extreme heat.

5. Conclusion & Recommendations:

Heat-wave adaptation can reduce adverse health impacts among vulnerable households. Policies should prioritize public awareness campaigns, climate-health education, early-warning information, and accessible adaptation measures to strengthen household resilience and protect health and nutritional well-being in heat-prone areas of Punjab.

Keywords: Heat Waves, Human Health, Nutrition, Climate Change, Adaptation, Punjab, Pakistan

SECTION IX

**9. Agribusiness, Entrepreneurship, and Value Chain
Development**

14 Abstracts

Entrepreneurial Capacity Building for Sustainable Rural Livelihoods: A Training Needs Assessment of Farmers in Punjab, Pakistan

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1. Introduction:

Agricultural entrepreneurship enables farmers to develop innovative products, improve farm management, access markets, diversify income, and strengthen rural livelihoods. However, effective entrepreneurial engagement requires appropriate knowledge, skills, attitudes, and competencies. Despite its importance, limited evidence exists on farmers' entrepreneurial training needs in Pakistan. This study addresses this gap by assessing entrepreneurial competencies and identifying priority training areas among farmers in the mixed cropping zone of Punjab.

2. Objectives:

The study aims to assess farmers' entrepreneurial competencies, identify priority training needs, examine factors influencing entrepreneurial decision-making, and recommend strategies for strengthening agricultural entrepreneurship.

3. Methodology:

A cross-sectional survey was conducted in District Sahiwal using a randomly selected sample of 382 farmers. Data were collected through a pre-tested and validated interview schedule. Entrepreneurial competencies were assessed across opportunity, conceptual, relationship, organizing, strategic, and commitment domains. Descriptive statistics, correlation analysis, and multiple regression were employed using SPSS.

4. Results:

Most respondents were aged 40–60 years (44.8%), literate (79.28%), operated less than 12.5 acres (69.4%), and earned up to PKR 30,000 monthly (78.79%). Relationship competencies ranked highest, particularly contact with fellow farmers. Major training needs were identified in opportunity recognition, commitment, and conceptual competencies. Social, financial, and institutional constraints were prominent barriers. Fear of criticism and limited technology awareness negatively influenced entrepreneurial decision-making ($\beta = -0.274$).

5. Conclusion & Recommendations:

Farmers demonstrated moderate entrepreneurial capacity with significant training gaps. Agricultural extension departments should provide targeted entrepreneurship training, establish agribusiness support centers with TEVTA, promote practical startup training, and facilitate affordable machinery and interest-free financing to strengthen rural entrepreneurship and livelihoods.

Keywords: Agricultural Entrepreneurship, Training Needs Assessment, Entrepreneurial Competencies, Rural Livelihoods, Smallholder Farmers

Digital Payment Adoption and Financial Decision-Making: Implications for Financial Inclusion

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1. Introduction:

Digital payment technologies, including mobile wallets, online banking, and debit and credit cards, are transforming financial practices by improving convenience, efficiency, security, and accessibility. In Pakistan, digital payments are increasingly popular among younger consumers, particularly Generation Z. However, limited empirical evidence exists on how digital payment adoption influences financial decision-making among this population. Understanding these relationships is important for promoting responsible digital finance and strengthening financial inclusion.

2. Objectives:

This study examines the effect of digital payment adoption on financial decision-making among Generation Z in Pakistan. It further investigates the effects of perceived ease of use, perceived usefulness, and security and trust on digital payment adoption and assesses the moderating role of financial literacy.

3. Methodology:

Primary data were collected from 410 Generation Z respondents in Pakistan using purposive sampling and a structured questionnaire. The collected data were analyzed using appropriate statistical techniques to examine the relationships among perceived ease of use, perceived usefulness, security and trust, digital payment adoption, financial literacy, and financial decision-making.

4. Results:

The findings indicate that perceived ease of use, perceived usefulness, and security and trust have significant positive effects on digital payment adoption. Digital payment adoption also positively influences financial decision-making. Furthermore, financial literacy strengthens the relationship between digital payment adoption and financial decision-making, suggesting that financially literate individuals are better able to use digital payment technologies for informed financial choices.

5. Conclusion & Recommendations:

Digital payment adoption can enhance financial decision-making and promote financial inclusion among Generation Z in Pakistan. Policymakers, financial institutions, educational institutions, and FinTech providers should promote secure digital payment systems alongside financial literacy initiatives to encourage responsible, inclusive, and sustainable digital financial practices.

Keywords: Digital Payment Adoption, Financial Decision-Making, Generation Z, Financial Literacy, Financial Inclusion

Digital Financial Literacy and Financial Competence: A Women Prospect

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1. Introduction:

The rapid expansion of financial technology (FinTech) has transformed financial services and created new opportunities for digital financial inclusion. However, a persistent gender gap in digital financial engagement remains a concern, as professional competence does not necessarily translate into digital financial competence. Strengthening women's digital financial literacy is therefore essential for improving financial security, independence, and empowerment.

2. Objectives:

This study examines the effects of five dimensions of digital financial literacy, digital financial knowledge, awareness of digital financial services, digital financial tool usage, online financial security and risk control, and digital financial attitude and behavior, on the financial competence of women bank employees in Faisalabad, Pakistan.

3. Methodology:

A quantitative cross-sectional research design was employed. Primary data were collected using a 38-item structured self-administered Likert-scale questionnaire adapted from internationally validated instruments. Purposive sampling was used to select women employees working in commercial banks in Faisalabad. Of the 360 questionnaires distributed, 344 were successfully received, yielding a response rate of 95.6%. The data were analyzed using multivariate statistical techniques.

4. Results:

The findings confirmed three significant relationships. Digital financial attitude and behavior had the strongest positive association with financial cybersecurity ($\beta = 0.496$, $p < 0.001$), followed by digital financial knowledge ($\beta = 0.194$, $p < 0.001$) and online financial security and risk control ($\beta = 0.147$, $p = 0.013$). Awareness of digital financial services and digital financial tool usage were not statistically significant in the multivariate model.

5. Conclusion & Recommendations:

Financial competence among women depends on the integration of digital financial knowledge, security awareness, risk management, and positive financial attitudes and behaviors. Policymakers and financial institutions should develop behavior-oriented, security-focused digital financial literacy programs to strengthen women's financial empowerment and secure participation in Pakistan's digital economy.

Keywords: Digital Financial Literacy, Financial Competence, Digital Financial Knowledge, Online Financial Security, Digital Financial Behavior

Investigating the Nexus of Digital Payments and Banking Performance

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1. Introduction:

Rapid digital transformation has reshaped the global banking industry, with digital payment systems becoming increasingly important for improving transaction efficiency, accessibility, convenience, and customer engagement. In developing economies such as Pakistan, the expansion of mobile banking applications, digital wallets, and online transaction platforms is creating new opportunities for banks to improve service delivery and competitiveness. However, empirical evidence regarding the relationship between digital payment adoption and banking performance remains limited at the local level.

2. Objectives:

This study examines the impact of digital payment growth on the performance of public and private sector banks in Faisalabad, Pakistan. It also investigates the factors influencing the adoption and utilization of digital banking platforms and their contribution to operational efficiency and customer satisfaction.

3. Methodology:

A quantitative research design was employed using primary data collected through a structured questionnaire from customers of public and private sector banks in Faisalabad. Respondents were selected through convenience sampling. The collected data were analyzed using the Statistical Package for Social Sciences (SPSS) for descriptive analysis and Structural Equation Modeling using Partial Least Squares (SEM-PLS) for examining relationships among the study variables.

4. Results:

The findings indicate that digital payment services contribute positively to banking performance by enhancing transaction convenience, service accessibility, operational efficiency, and customer satisfaction. The results further highlight the importance of reliable digital infrastructure, user-friendly platforms, and effective digital service delivery in encouraging customers to adopt and utilize electronic payment systems.

5. Conclusion & Recommendations:

Digital payment adoption represents an important driver of banking performance in Pakistan. Public and private banks should strengthen digital infrastructure, improve platform security and usability, enhance customer awareness, and invest continuously in digital innovation. Policymakers and financial regulators should support an enabling environment for secure and inclusive digital financial services.

Keywords: Digital Payment, Banking Performance, SEM-PLS, Public Banks, Private Bank

Evaluating the Microfinance and Financial Well-being linkage in lens of SMEs

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1. Introduction:

Microfinance has emerged as an important source of financial support for small and medium-sized enterprise (SME) owners in Pakistan, particularly those facing barriers to conventional financial services. Despite the expansion of microfinance programs, many SME owners continue to experience financial constraints. Limited empirical evidence exists regarding the mechanisms through which microfinance contributes to the financial well-being of SME owners.

2. Objectives:

This study examines the impact of microfinance on the financial well-being of SME owners and investigates the mediating role of financial literacy. Financial literacy is assessed through three dimensions: financial attitude, financial behavior, and financial skills.

3. Methodology:

A quantitative research design was employed using primary data collected from 408 SME owners in Faisalabad through purposive sampling. Data were gathered using a structured questionnaire and analyzed through the Statistical Package for Social Sciences (SPSS) and Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine direct and mediated relationships among the study variables.

4. Results:

The findings demonstrate that microfinance has a significant positive effect on both financial literacy and financial well-being. Financial literacy also significantly improves financial well-being and mediates the relationship between microfinance and financial well-being. All three dimensions of financial literacy, financial attitude, financial behavior, and financial skills, show significant contributions to improved financial outcomes.

5. Conclusion & Recommendations:

The findings suggest that integrating financial literacy programs with microfinance services can strengthen financial decision-making, business performance, and the long-term financial well-being of SME owners. Microfinance institutions should incorporate practical financial education into lending programs. However, the cross-sectional design and reliance on SME owners' responses may limit causal interpretation and generalizability.

Keywords: Microfinance, Financial Literacy, Financial Well-being, Financial Behavior, Financial Attitude

Benford's Law and Earnings Management Risk in Pakistan's Listed Agri-Food Processing Firms: Evidence from Sugar, Food, and Edible-Oil Sectors

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1. Introduction:

Earnings management occurs when managers manipulate reported financial information to present a more favorable picture of firm performance. This issue is particularly relevant in Pakistan's agri-food processing sector, where concentrated ownership, limited regulatory oversight, government pricing and subsidy arrangements, and exposure to currency and commodity shocks may increase reporting risks. However, evidence of potential earnings irregularities in listed agri-food firms remains limited.

2. Objectives:

This study examines whether revenue and net-income figures reported by Pakistan Stock Exchange (PSX)-listed agri-food firms conform to Benford's Law and identifies deviations that may serve as forensic indicators of potential earnings irregularities.

3. Methodology:

Audited annual reports from 2014–2024 were analyzed for 49 continuously listed PSX firms across Sugar and Allied Industries (28), Food and Personal Care Products (19), and Vanaspati and Allied Industries (2). First-digit frequencies were extracted from 526 revenue and 366 net-income firm-year observations. Deviations from Benford's expected distribution were assessed using Chi-Squared, Mean Absolute Deviation (MAD), and Kolmogorov-Smirnov tests.

4. Results:

Food and Personal Care Products showed significant revenue deviation ($\chi^2=16.498$, $p=0.036$; $MAD=0.0250$), exceeding net-income deviation ($MAD=0.0201$). Sugar and Allied Industries' revenue conformed ($\chi^2=6.353$, $p=0.608$; $MAD=0.0136$), whereas net income showed greater deviation ($MAD=0.0221$). Vanaspati and Allied Industries recorded the largest deviations, particularly for revenue ($\chi^2=17.870$, $p=0.022$; $MAD=0.0808$).

5. Conclusion & Recommendations:

The findings indicate potential digit-level reporting irregularities across Pakistan's agri-food sectors. Revenue deviations were greater in two of three sectors. Risk-based audit screening, regulatory surveillance, and forensic analysis are recommended to strengthen financial reporting integrity.

Keywords: Benford's Law; Earnings Management; Agri-Food Firms; Forensic Accounting; Pakistan Stock Exchange

Digital & IoT-Enabled Cold Chain Monitoring in Multi-Commodity Value Chains: Evidence from South Asia

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1. Introduction:

Cold chain inefficiencies remain a major constraint in South Asian agricultural value chains, contributing to substantial post-harvest losses of perishable and semi-perishable commodities. Limited real-time monitoring of temperature, humidity, and transportation conditions affects food safety, market access, and smallholder profitability. Internet of Things (IoT)-enabled technologies offer opportunities to improve cold chain visibility, traceability, and efficiency. However, their adoption remains fragmented due to financial, infrastructural, technological, and regulatory constraints. This study examines the role of digital and IoT-enabled monitoring in strengthening multi-commodity cold chains across South Asia.

2. Objectives:

The study aims to assess IoT-enabled cold chain adoption, identify structural, financial, technological, and regulatory barriers, and propose evidence-based strategies for scalable, inclusive, and resilient cold chain modernization.

3. Methodology:

A qualitative policy analysis was conducted using a systematic review of peer-reviewed literature, government policies, and institutional reports from Pakistan, India, Bangladesh, and Sri Lanka published between 2015 and 2025. Secondary evidence from FAO, World Bank, and ADB was incorporated to contextualize regional cold chain gaps. Comparative and thematic analyses were used to identify adoption patterns, constraints, and policy priorities.

4. Results:

Findings indicate that IoT adoption remains limited and is concentrated among large agri-exporters and urban-linked supply networks. Major constraints include high sensor and infrastructure costs, unreliable rural electricity, limited digital literacy, and inadequate interoperability standards. Pakistan and Bangladesh face substantial infrastructure gaps, whereas India's public-private initiatives demonstrate greater progress in reducing post-harvest losses. Targeted subsidies, public investment, and mandatory cold chain standards can accelerate adoption and improve market integration.

5. Conclusion & Recommendations:

Digital cold chain transformation requires coordinated investment in infrastructure, technology subsidies, interoperable standards, and smallholder-inclusive models. Public-private partnerships and IoT-ready agricultural logistics can reduce post-harvest losses, strengthen food safety, enhance export competitiveness, and build climate-resilient food value chains.

Keywords: IoT cold chain, Value chain disruption, Post-harvest losses, Agri-food policy, South Asia logistics

Macroeconomic Drivers of Brain Drain Under Globalization: An Empirical Analysis

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1. Introduction:

Brain drain, characterized by the migration of highly skilled professionals from developing to developed economies, represents a significant loss of human capital and expertise. Pakistan has experienced increasing skilled migration, raising concerns regarding its implications for economic development, productivity, and institutional capacity. Macroeconomic instability, weak governance, inadequate infrastructure, limited employment opportunities, and lower quality of life may encourage skilled professionals to seek opportunities abroad. Under globalization, these push factors interact with international pull factors, facilitating greater mobility of skilled human resources.

2. Objectives:

This study aims to examine the macroeconomic determinants of brain drain in Pakistan, focusing on governance, financial stability, infrastructure, social openness, and quality of life, while assessing the economic, demographic, and socio-political factors influencing skilled migration.

3. Methodology:

The study employs secondary annual data covering 2002–2024. The Autoregressive Distributed Lag (ARDL) model is used to investigate both short-run and long-run relationships between brain drain and selected macroeconomic determinants. The approach enables assessment of the dynamic effects of economic and institutional conditions on skilled migration decisions.

4. Results:

The findings indicate that macroeconomic conditions significantly influence brain drain in Pakistan. Weak financial stability, inadequate infrastructure, governance challenges, limited economic opportunities, and unfavorable living conditions contribute to migration pressures among skilled professionals. The results further demonstrate that both domestic push factors and international pull factors shape skilled migration decisions, with persistent macroeconomic weaknesses contributing to the long-term loss of human capital.

5. Conclusion & Recommendations:

Reducing brain drain requires policies that strengthen macroeconomic stability, governance, infrastructure, employment opportunities, and quality of life. Retention strategies should focus on creating competitive professional environments and sustainable economic opportunities to preserve skilled human capital and support Pakistan's long-term development.

Keywords: Brain Drain, Push Factors, Financial Stability, Infrastructure, Standard of Living, ARDL

Agribusiness Entrepreneurship: A Systematic Review of Emerging Trends, Theoretical Perspectives, and Future Research Directions

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1. Introduction:

Agribusiness entrepreneurship has emerged as an important research domain linking entrepreneurship, agricultural development, innovation, and sustainable food systems. The transformation of agriculture from production-oriented activities toward market-driven entrepreneurial ecosystems has created opportunities for value creation through innovation, value-chain integration, digital technologies, and sustainable business models. However, existing research remains fragmented across individual, organizational, and institutional perspectives.

2. Objectives:

This study systematically reviews literature on agribusiness entrepreneurship to identify emerging research themes, theoretical perspectives, methodological trends, knowledge gaps, and future research directions, with particular emphasis on entrepreneurial competencies, innovation, digital transformation, sustainability, and institutional support.

3. Methodology:

A systematic literature review approach was employed to synthesize contemporary scholarly research on agribusiness entrepreneurship. The literature was examined thematically to identify dominant research areas, theoretical foundations, methodological approaches, and emerging knowledge gaps related to entrepreneurial behavior, innovation capability, market participation, value-chain development, and enabling ecosystems.

4. Results:

The review identifies five major thematic clusters: entrepreneurial competencies and behavior; innovation-driven agribusiness development and technology adoption; sustainable and socially responsible agricultural enterprises; institutional and ecosystem support; and value-chain entrepreneurship and market-oriented transformation. Findings indicate that agribusiness entrepreneurial performance is influenced by entrepreneurial orientation, access to finance, technological readiness, social networks, institutional support, market connectivity, and sustainability practices. Research gaps remain in digital entrepreneurship, dynamic capabilities, cross-country comparisons, and long-term venture sustainability.

5. Conclusion & Recommendations:

Agribusiness entrepreneurship provides an important pathway for rural transformation and sustainable food-system development. Future research should adopt ecosystem-based approaches examining interactions among entrepreneurs, markets, financial institutions, technology providers, and policymakers. Greater attention to digital innovation, dynamic capabilities, and sustainable business models can support resilient and competitive agribusiness enterprises.

Keywords: Agricultural entrepreneurship; Innovation capability; Sustainable agribusiness; Agri-food systems; Digital agriculture

Building Climate Resilient Agricultural Value Chains in Pakistan: Assessing Vulnerabilities, Market Risks, and Adaptation Strategies

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1. Introduction:

Climate change increasingly threatens agricultural production, markets, and food systems in Pakistan. Rising temperatures, erratic rainfall, floods, droughts, pest outbreaks, and water scarcity disrupt agricultural value chains, causing production losses, post-harvest inefficiencies, transportation disruptions, price volatility, and livelihood insecurity. While substantial research examines farm-level climate impacts, limited attention has been given to climate resilience across agricultural value chains as integrated systems.

2. Objectives:

This study synthesizes evidence on climate-induced vulnerabilities, market risks, and adaptation strategies across Pakistan's agricultural value chains and develops an integrated framework for strengthening resilience and supporting evidence-based policymaking.

3. Methodology:

A systematic literature review was conducted using peer-reviewed empirical and theoretical studies and reports from international organizations. Evidence was critically analyzed thematically to examine climate risks across input supply, production, aggregation, storage, processing, transportation, distribution, and marketing, alongside adaptation measures, institutional mechanisms, and emerging technologies.

4. Results:

The review indicates that climate shocks adversely affect all stages of agricultural value chains through production losses, supply disruptions, infrastructure damage, post-harvest losses, market instability, information asymmetry, and declining food security. Climate-smart agricultural practices, resilient infrastructure, digital market information systems, improved logistics, farmer organizations, financial inclusion, agricultural insurance, and effective value-chain governance emerge as important mechanisms for enhancing adaptive capacity. Stronger coordination among farmers, markets, financial institutions, government agencies, and private-sector actors is also essential for reducing market risks and improving resilience.

5. Conclusion & Recommendations:

Building climate-resilient agricultural value chains requires integrated interventions combining climate-smart technologies, digitalization, resilient infrastructure, financial services, insurance, and inclusive governance. Policymakers should strengthen institutional coordination and invest in smallholder-focused adaptation systems to improve market efficiency, food security, and sustainable agricultural development in Pakistan.

Keywords: Climate change; Agricultural value chains; Climate resilience; Market risks; Sustainable agriculture; Market efficiency; Sustainable Development Goals (SDGs)

Determinants of Compliance Behavior of Farmers towards Agriculture Taxation in Punjab

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1. Introduction:

Agricultural tax compliance is an important fiscal and governance issue in developing economies, where effective taxation contributes to public revenue, equitable resource distribution, and sustainable development. However, farmers' compliance with agricultural taxation remains relatively low in Punjab, Pakistan. This study investigates the socioeconomic, institutional, and perception-based factors influencing farmers' tax compliance behavior.

2. Objectives:

The study aimed to identify the key determinants of farmers' compliance with agricultural taxation and examine how institutional satisfaction, tax knowledge, perceptions of government services, and taxation practices influence compliance behavior in Punjab.

3. Methodology:

Primary data were collected from 557 farmers using a structured questionnaire and cluster sampling technique. Farmers' compliance behavior was assessed in relation to socioeconomic characteristics, tax awareness, perceptions of taxation, institutional satisfaction, and government services. Binary Logistic Regression was employed to estimate the factors significantly associated with agricultural tax compliance.

4. Results:

The findings indicate that education, tax knowledge, satisfaction with tax authorities, perceptions of tax contributions to society and the agricultural sector, and lower levels of crime and conflict significantly and positively influence farmers' tax compliance. In contrast, perceptions of government tax wastage, indirect taxation in agriculture, and inadequate agricultural services have significant negative effects on compliance behavior. The results highlight the importance of both institutional trust and farmers' perceptions of taxation in shaping compliance decisions.

5. Conclusion & Recommendations:

Improving agricultural tax compliance requires greater transparency, enhanced tax awareness, and more responsive tax administration. Strengthening farmers' satisfaction with tax authorities, demonstrating the productive use of tax revenues, improving agricultural services, and addressing concerns regarding indirect taxation can promote voluntary compliance and strengthen agricultural tax collection in Punjab.

Keywords: Compliance Behavior; Agricultural Taxation; Tax Knowledge; Binary Logistic Regression; Tax Authorities

Social Capital and Entrepreneurial Intentions among Women Farmers in Punjab, Pakistan

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1. Introduction:

Entrepreneurship is an important driver of economic development, innovation, employment generation, and social mobility, particularly in rural communities. Women's entrepreneurship can contribute substantially to household welfare and local economic development; however, restrictive social norms, limited resources, and weak support networks often constrain rural women's entrepreneurial participation. Social capital, including community participation, trust, and supportive relationships, can potentially strengthen women's entrepreneurial intentions. This study examines the role of social capital in shaping entrepreneurial intentions among rural women farmers in Punjab, Pakistan.

2. Objectives:

The study aimed to assess the influence of social capital on rural women's entrepreneurial intentions and identify the community-level factors that encourage women to pursue entrepreneurial activities.

3. Methodology:

Primary data were collected from 120 rural women in Punjab using a purposive sampling technique. A structured questionnaire was used to obtain information on entrepreneurial intentions and dimensions of social capital. Quantitative analysis was conducted using an Ordered Probit model to estimate the effects of social capital and related factors on women's entrepreneurial intentions.

4. Results:

The findings demonstrate that social capital plays a significant role in strengthening women's entrepreneurial intentions. Participation in local community activities (PLC) and feelings of trust and safety (FTS) were found to have significant positive effects on entrepreneurial intentions. The results indicate that stronger community engagement, social interaction, and supportive local environments can enhance women's willingness to initiate entrepreneurial activities. Social connections with friends, family, and community members also provide an enabling environment for entrepreneurial decision-making.

5. Conclusion & Recommendations:

Strengthening social capital can promote rural women's entrepreneurship and local economic development. Entrepreneurship programs should emphasize community participation, neighborhood networks, trust-building, and family and peer support alongside financial and technical assistance.

Keywords: Entrepreneurial Intention; Rural Women; Social Capital; Community Participation; Local Economic Development

From Skepticism to Adoption: Analyzing the Role of Cybersecurity Assurance and Trust on Digital Payment Usage

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1. Introduction

The rapid expansion of digital payment technologies has transformed financial transactions, particularly among Generation Z. Despite increasing adoption, concerns regarding cybersecurity, privacy, and institutional trust continue to influence consumers' willingness to use digital payment systems. While previous studies have emphasized perceived usefulness, ease of use, and technological acceptance, limited attention has been given to cybersecurity assurance and institutional trust as mechanisms for overcoming skepticism toward digital payments in Pakistan.

2. Objectives

This study examines the effects of cybersecurity assurance and institutional trust on digital payment usage among Generation Z consumers in Pakistan. It further investigates whether institutional trust strengthens users' confidence in the security and reliability of digital payment systems.

3. Methodology

A quantitative research design was employed using a structured questionnaire to collect primary data from Generation Z consumers in Pakistan. Respondents were selected through convenience sampling. The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS) and Partial Least Squares Structural Equation Modeling (SEM-PLS) to assess relationships among cybersecurity assurance, institutional trust, and digital payment usage.

4. Results

The findings indicate that cybersecurity assurance and institutional trust play important roles in shaping consumers' willingness to use digital payment systems. Stronger perceptions of security and greater confidence in financial institutions are associated with increased acceptance and usage of digital payments.

5. Conclusion & Recommendations

The study highlights cybersecurity assurance and institutional trust as critical drivers of digital payment adoption among Generation Z. Banks, fintech providers, and regulators should strengthen cybersecurity infrastructure, enhance transparency, and implement trust-building measures to promote secure, inclusive, and sustainable digital payment adoption in Pakistan.

Keywords: Cybersecurity Assurance, Institutional Trust, Digital Payment Usage, Generation Z

Impact of Cash and Bonus Dividends on Share Prices of Non-Financial Sector in Pakistan

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1. Introduction

Dividend announcements provide important information to investors and may influence stock prices through signaling and market expectations. This study examines how cash and bonus dividend announcements affect share prices of non-financial firms listed on the Pakistan Stock Exchange (PSX), with particular emphasis on market reactions around announcement dates.

2. Objectives

The study aims to assess the effects of cash dividend announcements on share prices, evaluate investor responses to bonus dividend announcements, and examine sector-wise variations in stock price reactions among non-financial companies listed on the PSX.

3. Methodology

A quantitative research design based on the Event Study Methodology was employed. Dividend announcements were treated as information events, while abnormal returns were estimated by comparing actual returns with expected returns derived from the market model using the KSE-100 Index as the benchmark. Secondary data were obtained from the Pakistan Stock Exchange and Investing.com for 2022–2025. From the PSX-listed population, financial firms were excluded because of their distinct regulatory and dividend structures. Using purposive sampling and predefined data-availability and event-screening criteria, 83 dividend-paying non-financial firms were selected. Average Abnormal Returns (AAR) and Cumulative Average Abnormal Returns (CAAR) were used to assess market reactions.

4. Results

The findings indicate abnormal returns around dividend announcement dates; however, most observed effects were statistically insignificant. Cash dividend announcements generated relatively more stable abnormal returns than bonus dividend announcements. Sector-wise analysis further revealed heterogeneous investor responses across non-financial sectors.

5. Conclusion & Recommendations

The findings suggest that dividend announcements have weak informational content in the PSX and provide limited support for dividend signaling theory. The observed market behavior is broadly consistent with semi-strong-form market efficiency. Investors and firms should therefore consider broader market and firm-specific factors when evaluating dividend announcements.

Keywords: Cash Dividends, Bonus Dividends, Share Prices, Non-Financial Sector, Pakistan Stock Exchange

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