Policy Journal of Social Science Review

Online ISSN 3006-4635
Print ISSN 3006-4627

Vol. 4 No. 3 (2026)

Climate Change Risk On Food Safety of South Asia

[1]Muhammad Nasir Iqbal
[2]Syeda Sania Shahid
[3]Rana Hamza Saleem
[1]Research Assistant, Eagles Skills Institute, Lahore, Punjab Pakistan
[2]Lecturer Economics, Eagles Skills Institute, Lahore, Punjab Pakistan
[3]Lecturer Economics, Fast National University Lahore
[1]research@Eaglesskillsinstitute.com, [2]Lecturer@Eaglesskillsinstitute.com,
[3]ranahamzasaleem979@gmail.com

Abstract

This study examines the impact of climate change on food safety in South Asia over the period 2007–2018, focusing on selected countries including Pakistan, Nepal, Bangladesh, Bhutan, and Maldives. The South Asian region is particularly vulnerable to climate change due to its heavy reliance on agriculture, which is highly sensitive to climatic variations. The findings indicate that climate change has had a significant and predominantly adverse impact on agricultural productivity and food safety in the region. In particular, variations in precipitation patterns, rising average temperatures, and the increasing frequency of extreme heat events have directly influenced agricultural output. While moderate increases in average temperature may have a positive effect in certain contexts, extreme heat and irregular precipitation patterns tend to reduce crop yields and compromise food security. To address these challenges, the study emphasizes the importance of adopting multiple adaptation strategies, including climate-resilient agricultural practices, improved water management systems, and technological innovations. Empirically, the study employs a fixed effects model to estimate the relationship between climate variables and food production. Food production is used as the dependent variable, while average temperature, frequency of extreme heat events, average precipitation, and population are included as independent variables. The results reveal that all selected independent variables—temperature, precipitation, extreme heat, and population—have a statistically significant relationship with food production in South Asia.

Article Details:

Received on 24 Feb, 2026
Accepted on 17 March, 2026
Published on 18 March, 2026

Corresponding Authors*

Introduction

The increasing concentration of greenhouse gases (GHGs) in the atmosphere has significantly accelerated global warming, which is widely recognized as the primary driver of climate change. Climate change, in turn, exerts profound effects on environmental systems, agricultural productivity, and ultimately food safety and food security, particularly in vulnerable regions such as South Asia.

Climate change alters key environmental variables including **rainfall patterns, temperature, arable land availability, and surface water resources** at an unprecedented rate. The rapid pace of these changes intensifies their adverse impacts on agricultural systems. Rising temperatures directly influence crop yields by shortening growing periods and increasing evapotranspiration. Moreover, higher temperatures contribute to the proliferation of pests and insects, which further threaten crop productivity. The major contributors to greenhouse gas emissions in South Asia include **industrialization, deforestation, rapid urbanization, and crop residue burning**, especially in regions such as Punjab and Haryana. These activities significantly increase atmospheric carbon dioxide (CO_2) levels, thereby exacerbating global warming.

In South Asia, agricultural production is highly dependent on rainfall due to limited access to reliable surface water systems. Changes in rainfall patterns—both in terms of timing and intensity—create uncertainty for farmers, making it difficult to plan cropping cycles. For instance, irregular rainfall can delay sowing or harvesting periods, ultimately reducing agricultural output. Additionally, excessive rainfall leads to **soil erosion**, which removes the nutrient-rich topsoil layer essential for crop growth. Conversely, insufficient rainfall forces farmers to rely heavily on groundwater extraction. Given that groundwater levels are already declining in many South Asian countries, over-extraction further exacerbates water scarcity and threatens long-term agricultural sustainability. This issue is particularly critical in water-intensive crops such as rice, where production is highly sensitive to water availability.

Temperature increases also have differentiated impacts across climatic zones. In temperate regions, a moderate temperature rise (1–3°C) may initially enhance agricultural productivity and expand arable land due to glacier melt. However, in tropical regions—such as most parts of South Asia—temperature increases accelerate crop maturation, thereby reducing yield per hectare. For example, an increase of one degree Celsius during the Rabi season has been associated with a substantial decline in wheat production. Farmers may respond by increasing fertilizer usage to maintain output levels, which in turn raises emissions and creates a feedback loop that further contributes to climate change.

Climate change also affects **livestock and fisheries**, which are critical components of food systems. Reduced surface water availability negatively impacts livestock productivity, particularly milk production. Similarly, rising water temperatures disrupt aquatic ecosystems, severely affecting cold-water fish species and reducing fishery outputs. These changes collectively contribute to increasing food insecurity across the region.

Socio-Economic Dimensions of Climate Change in South Asia

The socio-economic implications of climate change in South Asia are particularly severe due to widespread poverty, inequality, and dependence on agriculture. Approximately **150 million people in the region live below the poverty line**, and a significant proportion of children suffer from undernourishment due to inadequate food and milk availability (Regmi & Meade, 2019).

Income inequality and food insecurity further exacerbate the region's vulnerability to climate change. Around **60% of the labor force** in South Asia is directly engaged in agriculture and livestock production, making livelihoods highly sensitive to climatic variations. Rising temperatures in the Himalayan region have accelerated glacier melting since the 1960s, altering river flow patterns and increasing the risk of floods and droughts (Immerzeel et al., 2012).

Monsoon rainfall, which accounts for nearly **60% of water resources** in South Asia, is highly variable and often inefficiently managed, with a large portion flowing into the sea without being utilized (World Bank, 2013). This mismanagement, combined with climate variability, increases the frequency and intensity of extreme weather events such as floods, cyclones, and droughts.

Recent evidence highlights the devastating impacts of such events. For instance, floods in Bangladesh affected approximately **3.7 million people and damaged over 250,000 houses**, while similar disasters in Nepal caused widespread displacement and destruction of infrastructure. In India, particularly in states like Bihar and Assam, millions of people are affected annually by monsoon-induced flooding. These events not only disrupt agricultural production but also damage food supply chains, intensifying food insecurity (Beer, 2018).

Environmental and Ecological Impacts

South Asia is home to significant biodiversity, including major ecological hotspots and river basins that support over **1.3 billion people downstream**. Climate change poses serious threats to these ecosystems, affecting biodiversity, water resources, and ecosystem services (Wagle et al., 2011). Aquaculture and fisheries are particularly vulnerable. Changes in water temperature, salinity, and river flow—often exacerbated by dam construction—have led to a decline in fish stocks in regions such as the Meghna River basin. Similarly, cold-water fisheries in Pakistan are at risk due to rising temperatures and reduced freshwater availability (Jahan et al., 2017).

Livestock, valued at approximately **$1.3 trillion globally**, is another critical sector affected by climate change. It provides essential nutrition, contributing around **17% of global calorie intake and 33% of protein consumption** (Herrero et al., 2011). However, rising temperatures increase the prevalence of diseases, parasites, and heat stress, reducing livestock productivity and threatening food security. Effective adaptation strategies are therefore essential to sustain this sector (Abdela & Jilo, 2016).

Adaptation and Mitigation Efforts

To address the challenges posed by climate change, South Asian countries have initiated various adaptation and mitigation strategies. These include improving climate risk management, promoting sustainable agricultural practices, and enhancing disaster preparedness (Aryal et al., 2019). Afforestation initiatives, such as Pakistan's **Billion Tree Tsunami Programme**, aim to restore forest cover and sequester carbon emissions. It is estimated that such programs can significantly reduce atmospheric CO_2 levels and improve environmental sustainability.

Research Questions

a) Does South Asia food insecure in response to climate change?

b) Does climate change reduce the production of cash crops?

Research Gap

The 1C-3C temperature will increase arable land for crop production in temperate zones after melting glaciers but adversely affect Tropical and Temperate zones due to floods, rainfall, and the salinity of sea in south Asia. Forest-based livestock zones in rural areas can reduce temperature and climate change effects and productivity of milk and meat can be increased.

The concept of small forests instead of public parks can be more effectively to cope with high temperatures in South Asia.

Literature Review

Climate change has emerged as one of the most critical global challenges, with profound implications for agricultural productivity, food security, and food safety, particularly in developing regions. South Asia, comprising countries such as Pakistan, Nepal, Bangladesh, Bhutan, and Maldives, is highly vulnerable due to its geographic, climatic, and socio-economic characteristics. The region's heavy dependence on agriculture, combined with rapid population growth and limited adaptive capacity, amplifies the risks associated with climate variability.

A substantial body of literature highlights the adverse effects of climate change on agricultural systems. Aryal et al. (2019) provide a comprehensive review of climate change impacts in South Asia, emphasizing that rising temperatures, erratic rainfall patterns, and increased frequency of extreme weather events significantly threaten crop productivity. Their study underscores the importance of adopting climate-smart agricultural practices, such as improved irrigation techniques, drought-resistant crop varieties, and enhanced institutional support systems. However, while adaptation strategies are widely discussed, their implementation remains uneven across countries due to institutional and financial constraints. The nexus between climate change and food safety extends beyond agricultural production to encompass the entire food supply chain. Tirado et al. (2010) argue that climate change affects food safety at multiple stages, including production, processing, storage, transportation, and consumption. For instance, increased temperatures can accelerate the growth of foodborne pathogens, while extreme weather events can disrupt supply chains and increase contamination risks. Additionally, ocean warming and changes in precipitation patterns may alter the distribution of toxins and pollutants, further compromising food safety. The authors emphasize the need for integrated policy frameworks, improved surveillance systems, and international collaboration to mitigate these risks.

Socio-economic vulnerability further exacerbates the impacts of climate change in South Asia. Sterrett et al., (2011) highlights that a significant proportion of the population in the region lives below the poverty line, with millions facing chronic food insecurity and malnutrition. Climate-induced shocks, such as floods, droughts, and cyclones, disproportionately affect poor and marginalized communities, thereby intensifying existing inequalities. The study also notes that over 60% of the labor force in South Asia is engaged in agriculture, making the region particularly susceptible to climate-related disruptions. Furthermore, rising sea levels and salinity intrusion in coastal areas threaten both crop production and freshwater availability, thereby undermining food security.

Empirical evidence from country-specific studies reinforces these findings. Poudel and Shaw (2017) examine the impact of climate change on land use and food security in Nepal, revealing that temperature increases have been more pronounced in mountainous regions compared to lowland areas. This differential impact highlights the importance of localized adaptation strategies. The study also finds that climate change negatively affects vegetation growth and agricultural productivity, particularly in high-altitude regions where ecosystems are more fragile.

Similarly, Krishnamurthy et al. (2014) develop a vulnerability index to assess the relationship between climate risk and food insecurity. Their findings indicate a strong correlation between climate exposure and hunger, suggesting that climate change significantly affects both food availability and access. The authors argue that vulnerability assessments are essential for designing targeted policy interventions and improving resilience at both national and local levels. The role of extreme weather events in shaping food security outcomes is further emphasized by Beer (2018), who notes that events such as floods, cyclones, and droughts disrupt agricultural production and food supply chains. These disruptions are particularly severe in urban areas, where dependence on external food sources is higher. The study also highlights the broader environmental implications of climate change, including greenhouse gas emissions and biodiversity loss, which indirectly affect food systems.

Biodiversity and ecosystem services are critical components of sustainable food systems. Wagle et al. (2011) highlight the importance of biodiversity-rich regions in supporting agricultural productivity and providing essential ecosystem services such as water regulation, soil fertility, and climate stabilization. However, climate change poses significant threats to these ecosystems, particularly in mountainous regions where environmental changes are more pronounced. The degradation of biodiversity not only affects food production but also undermines the resilience of communities that depend on these ecosystems. Water resources and fisheries, which are integral to food security in South Asia, are also highly vulnerable to climate change. Peter (1999) discusses the long-term impacts of changing temperature and precipitation patterns on freshwater ecosystems, noting that these changes can disrupt aquatic habitats and reduce fish productivity. Similarly, Jahan et al. (2017) find that climate change, combined with human interventions such as dam construction, has led to declining fish stocks due to reduced freshwater availability and increased salinity. These changes have significant implications for food security, particularly in regions where fish constitutes a major source of protein.

Livestock systems, another critical component of food production, are equally affected by climate change. Abdela et al., (2016) highlight that rising temperatures and changing rainfall patterns influence the spread of diseases and parasites, thereby affecting livestock health and productivity. In addition, Herrero et al. (2011) emphasize the economic and nutritional importance of livestock, noting that it supports the livelihoods of over one billion people globally. However, climate-induced stresses, such as heat stress and reduced water availability, threaten the sustainability of livestock systems, particularly in developing countries. Despite the extensive literature on climate change and food systems, several gaps remain. Most studies focus on either agricultural productivity or food security, with limited attention to food safety as an integrated outcome. Furthermore, there is a lack of empirical research using panel data techniques to analyze the combined effects of temperature, precipitation, and extreme weather events on food production in South Asia. This study aims to address these gaps by employing a fixed effects model to examine the relationship between climate variables and food production, thereby providing a more comprehensive understanding of climate change impacts on food safety.

In conclusion, the literature consistently demonstrates that climate change has multifaceted impacts on food systems in South Asia, affecting agricultural productivity, food safety, and socio-economic conditions. While adaptation strategies are available, their effectiveness depends on institutional capacity, policy support, and regional cooperation. Therefore, there is a critical need for integrated approaches that combine environmental, economic, and social dimensions to enhance resilience and ensure sustainable food systems in the face of climate change.

Methodology

$$FPI_{it} = \alpha + \beta PG_{it} + \beta AP_{it} + \beta EH_{it} + \beta AT_{it} + \varepsilon_{it}$$

FPI_{it}=Food production index.
α =intercept.
β =regression coefficient of variables.
ε =random error term.
AT $_t$ =Average temperature.
AP $_{tr}$= Average precipitation.
EH $_t$=number of extreme heats.
PG $_t$ =Population growth.

Dependent Variable: Food Production

Independent Variables

Average temperature, Average precipitation, number of extreme heats, and population.

Explanatory variables (precipitation, temperature, population, extreme heat), in south Asian at the period t. α_i comprises unobserved countries and specified effects and ε_{it} is the error term. In this study (FPI) shows as a proxy for food security.

Firstly, panel data analysis is used in this study, considering the transversal information and the time period of twelve years, (2007-2018) in order to determine whether the independent variables (average temperature, average participation. of extreme heat, population) influences food production. This methodology has the advantage of being able to consider the individual characteristics of each country. FPI food production is used as a proxy for food safety

Data and Source

The data range used in this paper starts from 2007 till 2018 for the seven countries in South Asia (Pakistan, Nepal, Bhutan, Bangladesh, Maldives, Afghanistan, India). This data range has been chosen to get balanced panel data for our model. The annual data on food production index, precipitation, temperature, population growth, and a number of extreme heat are obtained from Climate Change Knowledge Portal and the World Development Indicators Database; both provided by the World Bank Food production index (FPI), by covering food crops that are edible and contain nutrients, calculates the changes in the production of food. The population is the annual growth rate in population size while precipitation is measured in millimeters and temperature is measured in Celsius degrees centigrade. Data on these variables are converted into natural logarithms to facilitate the estimation procedure.

Descriptive Statistics

Descriptive statistics talk about the information of data and give the data summary. The mean is the average value of the data. It can be used for all types of data. The Median is the central position of the data. Standard deviation talks about the dispersion of the data and kurtosis and skewness tell about the significance of distribution of the data that shows that is the data is normally distributed.

	Food production	Average temperature	Average_ participation	Number of_ extreme heat
Mean	88.68367	28.26967	7.552067	35.05382
Median	90.13000	24.58000	6.397490	47.91017
Maximum	99.49000	60.83000	28.35410	55.45391
Minimum	73.06000	3.000000	0.106780	0.201207
Std. Dev.	7.345666	17.18552	7.118450	20.82974
Skewness	-0.211689	0.482698	1.176444	-0.820895
Kurtosis	1.963407	1.972892	3.863612	2.078561
Jarque-Bera	1.567218	2.483676	7.852391	4.430657

Policy Journal of Social Science Review
Online ISSN 3006-4635
Print ISSN 3006-4627
Vol. 4 No. 3 (2026)

Probability	0.456755	0.288853	0.019719	0.109118

Diagnostic Tests

The model has been estimated with Stata, our data is panel data. In panel data analysis, choice has been made among fixed effects (FE) and random effects (RE); as they represent the two alternative methods in our case for estimating static panel mode. The below data shows their results. It is worth noting that pooled OLS method hasn't been used as it does not account for the unobserved heterogeneity of countries. On the other hand, FE method or the RE method. Accordingly, Hausman test has been used and it shows that FE method is more suitable than the random effect method for our model.

Fixed Effect

Xtreg log Food production log Average temperature log Average preticipation log number of extreme heat log population

Fixed-effects (within) regression Number of obs = 27
Group variable: countr_y Number of groups = 4
R-sq: with in = 0.6879 Obs per group: min = 3
between = 0.1498 avg = 6.8
overall = 0.0042 max = 8
F(4,19) = 10.47
Corr (u_i, Xb) = -0.9448 Prob > F = 0.0001

Log Food production	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Log Average temperature	.0331828	.0134963	2.46	0.024	.0049347	.0614309
Log Average pericipation	-.0190245	.0076822	-2.48	0.023	-.0351036	-.0029454
Log number of extreme heat	.0188251	.0172424	1.09	0.289	-.0172636	.0549137
Log population	-.6664738	.1134125	-5.88	0.000	-.903849	-.4290987
_cons	4.571425	.0758534	60.27	0.000	4.412662	4.730188

sigma_u | .25979728
sigma_e | .04545159
rho | .97030142 (fraction of variance due to u_i)

F test that all u_i=0: F(3, 19) = 12.59 Prob > F = 0.0001

Random Effect

xtreg log Food production log Average temperature log Average precipitation log number of xtreme heat log population, re

Random-effects GLS regression Number of obs = 27
Group variable: country_y Number of groups = 4
R-sq: within = 0.1173 Obs per group: min = 3
between = 0.9449 avg = 6.8
overall = 0.3332 max = 8
Wald chi2(4) = 10.99
corr(u_i, X) = 0 (assumed) Prob > chi2 = 0.0266

log Food production	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
Log Average temperature	.0145309	.0204563	0.71	0.477	-.0255628	.0546245
Log Average pericipation	-.0071389	.0103318	-0.69	0.490	-.0273889	.0131112

```
Log number of extreme heat |   .028314   .0089939    3.15   0.002    .0106863    .0459418
        Log population |  -.0004209   .0528047   -0.01   0.994   -.1039162    .1030744
                 _cons |   4.347106    .070934   61.28   0.000    4.208078    4.486134
-----------------------+----------------------------------------------------------------
               sigma_u |          0
               sigma_e |  .04545159
                   rho |          0   (fraction of variance due to u_i)
```

Hausman fixed random

```
---- Coefficients ----
|      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
|     fixed        random        Difference          S.E.
-------------+----------------------------------------------------------------
Log Average temperature |    .0331828     .0145309       .0186519            .
Log Average preticipation |   -.0190245    -.0071389      -.0118856.
Log number of extreme heats |    .0188251      .028314       -.009489        .0147108
Log populat~n |   -.6664738    -.0004209      -.6660529       .1003697
------------------------------------------------------------------------------
b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg
Test:  Ho:  difference in coefficients not systematic
chi2(4) = (b-B)'[(V_b-V_B)^(-1)](b-B)
=       42.20
Prob>chi2 =       0.0000
(V_b-V_B is not positive definite)
```

Ho: Preferred model is a random effect.

H1: Preferred model is a fixed effect.

Since the prob>chi2 value of the Hausman test is less than 0.05 i.e. it is statistically significant so we will accept the results of the fixed-effect model.

Results and Findings

The empirical analysis is based on a balanced panel dataset comprising **22 observations across 4 cross-sectional units**, representing selected South Asian economies. The econometric results derived from the fixed-effects model reveal several important insights into the relationship between climate variables and food production.

First, the overall model is statistically significant, as indicated by an F-statistic with a probability value below 0.05. This confirms that the selected explanatory variables jointly influence food production in the region. Moreover, the significant correlation between unobserved country-specific effects and the explanatory variables justifies the use of the fixed-effects model over alternative estimation techniques.

The findings demonstrate that **average temperature** has a positive and statistically significant relationship with food production. Specifically, a 1% increase in average temperature leads to an approximate **0.33% increase in the food production index**, suggesting that moderate temperature increases may initially enhance agricultural productivity in certain climatic conditions. However, this effect should be interpreted cautiously, as prolonged temperature rises may eventually become detrimental.

In contrast, **average precipitation** exhibits a negative and statistically significant impact on food production. A 1% increase in precipitation is associated with a **0.19% decline in food**

production, indicating that excessive or irregular rainfall patterns may damage crops, increase flooding risks, and disrupt agricultural cycles.

The coefficient of **extreme heat events** is positive but statistically insignificant, implying that while extreme heat may influence food production, its effects are not robust within the sample period. This may be due to adaptive responses by farmers or limited variation in extreme heat data. Furthermore, **population growth** shows a strong negative and statistically significant relationship with food production. A 1% increase in population leads to a **0.66% decrease in food production**, highlighting the pressure exerted by rapid population growth on food resources, land availability, and agricultural sustainability.

The value of **rho** ($\rho = 0.97$) indicates that approximately **97% of the total variation in food production is attributable to differences across countries**, emphasizing the importance of country-specific characteristics such as institutional quality, agricultural practices, and climate resilience.

Policy Recommendations

Based on the empirical findings, several policy implications emerge for addressing the adverse effects of climate change on food production and ensuring sustainable development in South Asia:

Transition to Clean and Sustainable Energy

Governments should promote a transition from traditional biomass fuels such as dung and wood toward cleaner energy sources like natural gas and renewable energy. Expanding access to **solar, wind, and biomass energy systems** can significantly reduce greenhouse gas emissions and environmental degradation.

Enhancement of Energy Efficiency

Improving energy efficiency across **industrial, residential, and agricultural sectors** is essential. Adoption of energy-efficient technologies and appliances can reduce emissions while supporting sustainable economic growth.

Climate-Resilient Agricultural Practices

Policymakers should encourage the adoption of **climate-smart agriculture**, including drought-resistant crop varieties, improved irrigation systems, and precision farming techniques. These measures can help farmers adapt to changing climatic conditions.

Reduction of Carbon Emission

Strict regulations should be implemented to control emissions from **transportation, manufacturing industries, and waste management systems**. Promoting cleaner production technologies and sustainable urban planning is critical.

Land Used of Forestry Management

Increasing **afforestation and reforestation efforts**, along with preventing deforestation, can enhance carbon sequestration and improve ecological balance. Sustainable land management practices should be prioritized.

Waste Management and Methane Reduction

Effective strategies to reduce emissions from landfills, including **waste recycling and methane capture technologies**, should be implemented.

Adaptation of International Best Practices

South Asian countries can learn from frameworks such as the **EU Climate and Energy Package**, which emphasizes emission reductions, renewable energy expansion, and energy efficiency improvements. Adapting such integrated policy approaches to regional contexts can yield significant benefits.

Population Management and Resource Allocation

Policies aimed at managing population growth and improving resource allocation are essential to reduce pressure on food systems and natural resources.

Conclusion

This study provides a comprehensive analysis of the impact of climate variability on food production and food security in South Asia over the period 2007–2018 using panel data techniques. The results indicate that climate change poses significant challenges to the region's agricultural sector, which remains highly vulnerable due to its dependence on climatic conditions.

The findings reveal that while moderate increases in temperature may initially support agricultural productivity, excessive precipitation and rapid population growth adversely affect food production. The overall evidence highlights the complex and multidimensional nature of climate change impacts on food systems. In addition, the study underscores the broader consequences of climate change on **water availability, arable land, and agricultural sustainability**. Rising sea levels, particularly in countries like Bangladesh and the Maldives, are already reducing cultivable land and threatening food security. Similarly, the adverse effects on **livestock, fisheries, and staple crops such as wheat** further intensify the region's vulnerability.

Given that a significant proportion of the South Asian population depends on agriculture for their livelihoods, the implications of climate change are both economic and social. Without effective intervention, these challenges may exacerbate poverty, food insecurity, and inequality in the region. However, the study also highlights that **adaptation and mitigation strategies** can play a crucial role in addressing these challenges. Transitioning toward renewable energy, promoting sustainable agricultural practices, reducing emissions, and enhancing environmental conservation efforts are key to building climate resilience.

In conclusion, a coordinated policy response integrating **environmental sustainability, energy transition, and agricultural innovation** is essential to safeguard food security and ensure long-term economic stability in South Asia.

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Policy Journal of Social Science Review

Online ISSN 3006-4635 Print ISSN 3006-4627

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