frontiers in Environmental Science

ORIGINAL RESEARCH
published: 31 January 2022
doi: 10.3389/fenvs.2021.807681

Climate Extreme and Agriculture Development: Fresh Insight From Top Agri-Economics

liu lisha[1,2], *Apichit Maneengam*[3], *Supat Chupradit*[4]*, *Gadah Albasher*[5], *Ohoud Alamri*[5], *Nouf Ahmed Alsultan*[6] *and Afzal Ahmed Dar*[7]

[1]School of Business and Economics, University Putra Malaysia, Selangor Darul Eshan, Malaysia, [2]Engineer, Ecological Environment Monitoring Center of Chengdu, Chengdu, China, [3]Department of Mechanical Engineering Technology, College of Industrial Technology, King Mongkut's University of Technology North Bangkok, Bangkok, Thailand, [4]Department of Occupational Therapy, Faculty of Associated Medical Sciences, Chiang Mai University, Chiang Mai, Thailand, [5]Department of Zoology, College of Science, King Saud University, Riyadh, Saudi Arabia, [6]Faculty of Medicine and Health Sciences, University of Nottingham, Nottingham, United Kingdom, [7]School of Environmental Science and Engineering, Shaanxi University of Science and Technology, Xi'an, China

OPEN ACCESS

Edited by:
Gagan Deep Sharma,
Guru Gobind Singh Indraprastha University, India

Reviewed by:
Sanjeet Singh,
Chandigarh University, India
SPS Bedi,
Guru Gobind Singh Indraprastha University, India

***Correspondence:**
Supat Chupradit
supat.c@cmu.ac.th

Specialty section:
This article was submitted to Environmental Economics and Management,
a section of the journal Frontiers in Environmental Science

Received: 02 November 2021
Accepted: 09 December 2021
Published: 31 January 2022

Citation:
lisha l, Maneengam A, Chupradit S, Albasher G, Alamri O, Alsultan NA and Dar AA (2022) Climate Extreme and Agriculture Development: Fresh Insight From Top Agri-Economics. Front. Environ. Sci. 9:807681. doi: 10.3389/fenvs.2021.807681

A range of studies have been observed, covering the title of climate change and its linkage with the agriculture sector. This would justify the claim that changing environment has its several outcomes for which the agriculture sector cannot be ignored. The purpose of this study is to investigate the impact of various climate change dynamics and modelling on the four indicators of agriculture sector. Overall, five panel economies were selected having highest level of agriculture output in the world economy. The time duration of the study was during 1990–2018 with yearly data as collected from world development indicator or WDI. The study analysis was conducted while applying four panel regression models like ordinary least square, fixed effect estimator, least square dummy variable, and finally the random effect. For better understanding, study findings are empirically explained. The results confirm that both positive and negative impact of various proxies of climate change on agriculture dimension of selected economies. More specifically, it is observed that higher climate change in the form of carbon emission from different sources are causing a downturn effect on the agriculture export while at the same time, they are causing an up-ward shift in the agriculture import of selected economies. Besides, study has reasonably disrobed various policy implications both in theoretical and practical perspective. However, some limitations are also under observation. Firstly, this study considers the limited number of explanatory variables for reflecting the changing climate trends among top five agriculture economies of the world. However, there are still range of other factors which can be observed in the future studies to examine their influence on the selected indicators of agriculture industry. Secondly, this study has applied traditional panel models where no implication is observed for the dynamic panel methods like Generalized methods of Moments or GMM. Thirdly, this study has not provided any evidence for the cross-country analysis. Fourthly, this study has limited time span along with missing examination of both short run and long as well. Future studies may address these limitations for better implication in both theoretical and practical perspective.

Keywords: carbon emissions, economic growth, developing economic, green energy, sustainable production

INTRODUCTION

In the recent time, there is a growing evidence that greenhouse gases have already begun to warm the planet in a range of categories along with their economic, social and financial perspective [Ramanathan and Feng, 2009; Amen et al., 2020; Chien et al., 2020; Kamran et al., 2020). As per the report of Intergovernmental Panel on Climate Change (IPCC), 2007], if the issue of changing climate is not addressed on some serious ground, then the stock of greenhouse gasses is expected to grow over the next century as well (Mahasenan et al., 2003; Mendelsohn, 2008; De Salvo et al., 2013; Aleixandre-Benavent et al., 2017; Nawaz et al., 2020a; Nawaz et al., 2020b; Sun et al., 2020). These conditions have generated the extensive need of climate change modelling that could help to predict the climate changing for the long period of time. The climate models are considered as an extension of weather forecasting (Singh et al., 2021). However, weather models make predictions for short timespans and over specific areas while climate models analyze long time spans. Climate change modellings predict how conditions will change on average over the coming decades.

Although there are various impacts as expected from the global climate change, however, one of the growing concerns in the literature is that climate change has its direct impact on the agriculture sector and its output (Ali et al., 2017; Kumar et al., 2018; Kumari et al., 2020; Mahato, 2014). For example, there are many studies which have discussed the relationship between climate change and agriculture sector both in developed and developing economies (Calzadilla et al., 2013; Calzadilla et al., 2014; Chen et al., 2016; Foster and Kalenkoski, 2013; Ignaciuk and Mason-D'Croz, 2014). For example, Walthall et al. (2013) have provided their view that increasing carbon dioxide is causing more temperature along with the altered precipitation patterns for the agriculture productivity. Meanwhile such changing climate is found to be vulnerable to the livestock production system as well and also generate the need of climate change modellings that provide the climate conditions of coming decades. Additionally, the projection for the crops and livestock production system has revealed the fact that the effect from changing climate over the next 25 years will be mixed. The reason is that agriculture sector is significantly depending upon the range of economic system process which supports the productivity including the soil quality maintenance and water regulation as well. They have further predicted the fact that extreme climate change has an increasing influence on the value of total productivity of agriculture sector of the world (Dar et al., 2020; Dar et al., 2021a).

Based on the above discussions, the agriculture sector has played a significant role in the economy of the country and climate changes put adverse impact on it and need to be investigate the foremost solution. Thus, the present study examines the impact of climate changes predicted through climate change models on the agriculture development in New Zealand, Argentina, Australia, Japan, and Brazil. The remaining part of the study consist on the literature review, research methods, results and discussions and end with the implication, limitations and future directions.

LITERATURE REVIEW

The association between climate change and agriculture sector output has provided some meaningful theoretical and empirical perspectives, (Lehtonen et al., 2021; Malik et al., 2021; Ofoegbu and New, 2021). It is observed that focus of various studies in the present literature is not only the key issues as linked with the climate change and agriculture sector, but also to provide some outstanding policy implications, however, ignored the influence of climate change modelling role on the predictions of climate that also has impact on the agriculture sector (Dar et al., 2021b). For example, Adams et al. (1998) has claimed that climate is the primary determinant of agriculture sector and its productivity due to the fact that over the years, there is a dramatic change in the agriculture sector productivity due to environmental concerns in both developed and developing economies. Their paper has reviewed the literature regarding the physical and economic aspects in the field of climate change and environmental concerns but ignored the climate change modellings role. Mishra and Sahu (2014) have also explored the economic impact of climate change on the agriculture sector of coastal Odisha. The study findings have confirmed the fact that most of the climate and control variables have their significant influence on the net revenue per hectare of the region. Meanwhile, they have used the trends of various seasons over the time of 30 years and found that rising temperature might have its adverse impact on the coastal zone agriculture of Odisha.

Aydinalp and Cresser (2008) have claimed that climate is to be considered as among the primary factor for the agriculture production. However, the potential effects of climate change on the agriculture sector have motivated various researchers. Therefore, their study has considered the association between the climate change and agriculture in terms of livestock yield and its economic consequences. They also ignored the climate change models to predict the climate that also put positive role on the livestock yield and its economic consequences. Karimi et al. (2018) explain that impact of climate change on agriculture isstill something associated with lot of uncertainties. However, the changing climate is also expected to adversely affect the agriculture industry in the economies like Iran. Their study has aimed to provide documentary evidence about the linkage between climate change and its impact on the agriculture industry. It is confirmed that the changes in the level of yield production is reasonably depending upon the crop type along with the carbon emission, environmental situation, and fertilization effect without using the climate change models. Furthermore, for higher level of agriculture output, the efforts from the government are quite reasonable.

Maia et al. (2018) have focused on the Brazilin economy and expressed that it is already suffering some significant impacts from changing climate. However, agriculture technologies may also play their role towards attenuating the impact of extreme events in the natural environment. Meanwhile, ecosystem may also paly its role towards attenuating the impacts of agriculture production. Zhang et al. (2017) express their view and stated that climate change can shift of distribution of climatic variables like temperature, wind spend, humidity, sunshine, and evaporation as well without using the climate changing models. For this reason, their study has examined the impact of all these variables on the crop growth during the time of 1980–2010. Furthermore, their study has confirmed the fact that climate change is likely to reduce the production of crop like 36.25% for the rice, 18.26% for the wheat, and 45.10 percent for the corn in Chinese economy by the end of current century.

Bombelli et al. (2019) express that increasing level of population along with the food consumption and gas emission are providing some new experiences to the world. The title of Paris Agreement has been recognized as among the fundamental priorities for the safeguarding the food along with ending the issue of hunger. Furthermore, it also focuses on the vulnerabilities of the food production system. Islam and Nursey-Bray (2017) have observed the adaption to climate change in the agriculture sector of Bangladesh through the role of formal institutions. The study findings confirm the effectiveness of the formal institutions for the adaption of climate change in the agriculture sector by ignoring the climate change models. Additionally, they have argued that for building an adaptive agriculture culture in the region of Bangladesh, the role of formal institutions cannot be ignored. Husnain et al. (2018) have provided their empirical contribution for the climate change and agriculture. Their paper aims to investigate such relationship through incorporating the geographical instrument, longitude and altitude, temperature and climate change for the agriculture sector in 60 panel economies. The study findings confirm a negative linkage between the temperature and agriculture sector in the targeted economies. Furthermore, it is confirmed that magnitude for the coefficient of the temperature is mild which is approximately 20 percent comparatively to earlier studies. In addition, there are range of other studies who have considered the linkage between climate change and agriculture industry with mixed number of empirical findings (Calzadilla et al., 2014; Ignaciuk and Mason-D'Croz, 2014).

METHODS AND VARIABLE DESCRIPTION

This study is purely quantitative in nature which has considered seven dynamics of climate change and four from the agriculture industry. The regional context of the study confirms that it considers the five major agriculture economies: New Zealand, Argentina, Australia, Japan, and Brazil. The data for the targeted economies was collected from the official web portal of world bank group, named as world development indicator or WDI. The time duration of the study considers 1990–2018 with annual observations. For the study variables, key explanatory variables are observed as Nitrous oxide emissions measured through % change from 1990, Nitrous oxide emissions measured in terms of thousand metric tons of CO2 equivalent, Methane emissions is measured through % change from 1990, and Methane emissions is calculated as kt of CO2 equivalent. In addition, the other explanatory variables of the study consider the total greenhouse gas emissions observed as % change from 1990, total greenhouse gas emissions measured as kt of CO2 equivalent and other greenhouse gas emissions observed as % change from 1990. These measurements are also based on the climate change models. The values of all these independent variables are directly achieved from the WDI during the study period. In addition, our study has added four dependent variables which include Agricultural raw materials exports measured in terms of % of merchandise exports, Agricultural raw materials imports measured in terms of % of merchandise imports, agriculture, forestry, and fishing, value added in terms of % of GDP, and Agriculture, forestry, and fishing, value added measured through current US$. However, due to higher amount in USD, the last dependent variable is further transformed through taking the natural log and finally added in the regression models.

For testing the empirical relationship between the study variables this study has adopted four panel regression techniques. The first one is known as simple OLS estimation which considers the impact of all the explanatory variables on the main dependent variables, while observing the effect of error terms as well. This is one of the most cited method in the present literature which is used to express the quantitative association between the study variables (Ma et al., 2012; Foster and Kalenkoski, 2013; Bun and Harrison, 2014; Ohlson and Kim, 2015; Bun and Harrison, 2019). For examining the relationship between set of climate change indicators and agriculture industry variables, following OLS regression equations are developed.

$$\begin{aligned} AG.RMEX = {} & \partial + B_a NOE + B_b NOEM + B_c ME + B_d MEK \\ & + B_d MEK + B_e TGSE + B_f TGEK + B_g OGS + \mu \end{aligned} \tag{1}$$

$$\begin{aligned} AGRMIM = {} & \partial + B_a NOE + B_b NOEM + B_c ME + B_d MEK \\ & + B_d MEK + B_e TGSE + B_f TGEK + B_g OGS + \mu \end{aligned} \tag{2}$$

$$\begin{aligned} AFFVAD = {} & \partial + B_a NOE + B_b NOEM + B_c ME + B_d MEK \\ & + B_d MEK + B_e TGSE + B_f TGEK + B_g OGS + \mu \end{aligned} \tag{3}$$

$$\begin{aligned} L.AFFVUSD = {} & \partial + B_a NOE + B_b NOEM + B_c ME + B_d MEK \\ & + B_d MEK + B_e TGSE + B_f TGEK + B_g OGS + \mu \end{aligned} \tag{4}$$

To empirically test the above stated equations, STATA-15 is under consideration and findings for the above equations are provided in **Table 2** of the study through Model 1 to Model 4. After examining the association between climate change dynamics and agriculture industry factors in the selected economies, this study applies the least square dummy variable model which is a second model in the panel regression. The model of least square dummy variable helps to control and show the effect of various entities which are under observation in any study. For example, in current research, data for the five entities is collected for both dependent and independent variables. Through LSDV model, the heterogeneity effect among the various entities or unit of observation can be controlled up to a significant level. For applying the LSDV model, following regression equations are developed and empirically tested. The findings for the LSDV model are provided in **Table 3** of the study.

$$\begin{aligned} AG.RMEX_{it} = {} & \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} \\ & + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} \\ & + B_f TGEK_{it} + B_g OGS_{it} + \gamma 2E2 + \ldots + \gamma nEn \\ & + \delta 2T2 + \ldots + \delta tTt + uit \end{aligned} \tag{5}$$

$$AGRMIM_{it} = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + \gamma 2E2 + \ldots + \gamma nEn + \delta 2T2 + \ldots + \delta tTt + uit \quad (6)$$

$$AFFVAD_{it} = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + \gamma 2E2 + \ldots + \gamma nEn + \delta 2T2 + \ldots + \delta tTt + uit \quad (7)$$

$$L.AFFVUSD_{it} = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + \gamma 2E2 + \ldots + \gamma nEn + \delta 2T2 + \ldots + \delta tTt + uit \quad (8)$$

After applying the least square dummy variable model, next step is to apply the fixed effect regression model which only controls the heterogeneous effect for the different entities. However, the regression coefficient under fixed effect is almost similar to least square dummy variable model. The findings for the fixed effect regression model for all dependent variables are provided in **Table 4**.

$$AG.RMEX_{it} = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + \alpha i + eit \quad (9)$$

$$AGRMIMit = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + \alpha i + eit \quad (10)$$

$$AFFVADit = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + \alpha i + eit \quad (11)$$

$$L.AFFVUSDit = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + \alpha i + eit \quad (12)$$

Lastly, our study has applied the random effect model which assumes that unlike the fixed effects model, the variation across entities is assumed to be random and uncorrelated with the predictor or independent variables included in the model. Therefore, we study has applied the following regression equations for the random effect.

$$AG.RMEX_{it} = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + uit + \varepsilon it \quad (13)$$

$$AGRMIM_{it} = \partial + B_a NOEit + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + uit + \varepsilon it \quad (14)$$

$$AFFVADit = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + uit + \varepsilon it \quad (15)$$

$$L.AFFVUSD_{it} = \partial + B_a NOE_{it} + B_b NOEM_{it} + B_c ME_{it} + B_d MEK_{it} + B_d MEK_{it} + B_e TGSE_{it} + B_f TGEK_{it} + B_g OGS_{it} + uit + \varepsilon it \quad (16)$$

The findings for the above random effect regression equations are presented under **Table 5**.

RESULTS AND DISCUSSION

A detailed level of descriptive outcomes is provided under **Table 1** based on the all the study variables. The findings predict that highest mean score is observed from NEOEM, MEK, and TGEK. Whereas all these variables have provided the evidence for the relatively higher value of standard deviation as well. Furthermore, ME indicates the lowest mean score in all the top five agriculture economies as observed under present study. Additionally. our study has also conducted an individual descriptive analysis for all five targeted economies. In case of New Zealand, highest mean trend is reflected by Total greenhouse gas emissions (% change from 1990) which is 78,612.41, followed by Nitrous oxide emissions (thousand metric tons of CO2 equivalent) in terms of 14,886.9. The rest of the descriptive trends under present study are provided in **Table 1**.

Table 2 predicts the regression results for all the four dependent variables as presented in Model 1 to Model 4, respectively. It is observed that AG. RMEX, AGRMIM, AFFVAD, and L. AFFVUSD are the key dependent variable to reflect the agriculture economies for all the panel countries. The study findings confirm that the impact of Nitrous oxide emissions (% change from 1990) on the first dependent variable is highly significant and negative at 1 percent. This means that for every single unit increase in the value of Nitrous oxide emissions (% change from 1990), there is decline of −0.247 in the value of Agricultural raw materials exports (% of merchandise exports) during the study period of 1990–2018. This relationship is expressed through regression coefficient of −0.247 and standard error of 0.032, respectively. However, contrary to the above findings, the influence of Nitrous oxide emissions (thousand metric tons of CO2 equivalent) on the Agricultural raw materials exports (% of merchandise exports) is positively significant at 1 percent. Furthermore, similar relationship is observed between Methane emissions (% change from 1990) and agriculture export in the top five agriculture economies during the study period. However, the influence from MEK

TABLE 1 | Data of different variables collected from 1990–2018 for followed countries.

New Zealand

Variable	Mean	Max	Min	Stdeve
NOE	11.1694	25.58296	–0.95727	8.746914
NOEM	14,886.9	15,940	14,280	3,735.442
MEK	33,072.07	33,830	31,840	8,274.872
ME	2.110519	7.370646	–2.45781	2.433111
TGSE	13.9121	27.17266	–0.38797	9.536842
TGEK	78,612.41	84,250	70,440	20,110.24
OGS	–52.673	–1.48019	–85.5788	37.28458
AGRMEX	13.27934	18.91734	8.912395	2.934753
AGRMIM	0.872899	1.210776	0.616814	0.188721
AFFVAD	6.0485	7.981385	4.471293	1.730534
AFFFVAUSD	6.65E + 09	8.2E + 09	4.56E + 09	1.52E + 09

Argentina

Variable	Mean	Max	Min	Stdeve
NOE	17.11151	40.43137	–1.81079	15.02206
NOEM	41,147.24	48,340	35,380	11,019.18
MEK	112,914.1	123,540	105,660	28,734.14
ME	–3.90465	0.48392	–15.0284	4.339745
TGSE	24.45458	54.37849	0.237739	17.95444
TGEK	308,283.8	367,320	243,030	87,247.02
OGS	105.093	333.4832	–40.8418	98.33672
AGRMEX	1.713634	4.349714	0.881347	1.026199
AGRMIM	1.433508	2.492597	0.880018	0.608094
AFFVAD	6.372982	10.32817	4.457826	1.490358
AFFFVAUSD	2.4E + 10	3.12E + 10	1.62E + 10	4.73E + 09

Australia

Variable	Mean	Max	Min	Stdeve
NOE	2.597631	29.59701	–18.1761	11.23369
NOEM	78,110	109,130	54,650	24,257.75
MEK	145,624.8	175,690	118,280	39,278.4
ME	6.756071	18.23448	–2.18237	5.72375
TGSE	79.52351	157.4166	–0.58771	58.72834
TGEK	576,366.2	673,130	503,740	151,896.3
OGS	948.3549	2,120.761	–20.2875	763.1183
AGRMEX	5.270447	10.65632	2.134787	2.884597
AGRMIM	1.099	2.04973	0.586277	0.489087
AFFVAD	2.805155	4.209132	1.897969	0.564303
AFFFVAUSD	2.54E + 10	3.25E + 10	1.61E + 10	5.27E + 09

Brazil

Variable	Mean	Max	Min	Stdeve
NOE	20.10375	51.97623	0.02629	14.4406
NOEM	144,607.9	184,380	106,590	43,305.33
MEK	365,670	424,800	285,240	102,677.3
ME	23.38656	54.00997	1.471793	17.09733
TGSE	16.38607	86.11634	-24.5447	30.44566
TGEK	854,292.1	1105900	593,950	264,873.8
OGS	3.821635	99.33697	–76.2468	44.70101
AGRMEX	4.057687	5.657866	3.058174	0.966931
AGRMIM	1.831182	4.318985	1.007113	0.858802
AFFVAD	5.120731	8.536411	4.115756	1.047571
AFFFVAUSD	5.7E + 10	8.75E + 10	3.14E + 10	1.8E + 10

Japan

Variable	Mean	Max	Min	Stdeve
NOE	–14.9202	3.475043	–32.5638	13.16941
NOEM	23,282.07	31,350	18,010	7,276.075
MEK	28,440.34	37,850	21,110	8,807.921
ME	–26.8022	–2.39612	–41.8016	16.89647
TGSE	6.956999	13.35066	–1.1062	4.414434
TGEK	1257168	1338630	1171570	316,578.9
OGS	55.24606	95.86325	12.56603	32.50231
AGRMEX	0.607364	0.864253	0.464236	0.120886
AGRMIM	3.389171	7.280848	1.515555	1.981913
AFFVAD	1.261144	1.892111	0.996606	0.526087
AFFFVAUSD	5.41E + 10	6.62E + 10	3.98E + 10	2.14E + 10

NOE, means Nitrous oxide emissions in terms of % change from 1990; NOEM, means Nitrous oxide emissions in terms of thousand metric tons of CO2 equivalent; ME, means Methane emissions measured through % change from the year 1990; MEK, means Methane emissions observed through kt of CO2 equivalent during the study period; TGSE, means total greenhouse gas emissions as observed through % change from 1990; TGEK, indicates the total amount of greenhouse gas emissions (kt of CO2 equivalent); OGS, reflects the other greenhouse gas emissions (% change from 1990); AGRMEX, indicates Agricultural raw materials exports; AGRMIM, indicates Agricultural raw materials imports (% of merchandise imports); AFFVAD, indicates the amount of Agriculture, forestry, and fishing, value added measured through % of GDP; LAFFFVAUSD, reflects log value of Agriculture, forestry, and fishing, value added as 2015 US$.

TABLE 2 | Climate extreme and agriculture dynamics under OLS estimation.

Variables	(1)	(2)	(3)	(4)
	Model 1	Model 2	Model 3	Model 4
NOE	−0.247***	0.0684***	0.0846***	−0.00682
	(0.0324)	(0.00803)	(0.0141)	(0.00921)
NOEM	0.000535***	−5.23e-05***	−0.000097***	5.14e-06
	(4.00e-05)	(1.34e-05)	(2.49e-05)	(1.45e-05)
ME	0.212***	0.0387***	−0.0631***	−0.00724*
	(0.0159)	(0.00796)	(0.0125)	(0.00430)
MEK	−0.000322***	2.67e-05***	5.91e-05***	7.31e-06***
	(1.94e-05)	(5.49e-06)	(1.34e-05)	(2.08e-06)
TGSE	−0.0413**	−0.0807***	−0.0363***	0.0141**
	(0.0160)	(0.00739)	(0.0100)	(0.00720)
TGEK	−1.51e-05***	4.16e-06***	−3.71e-06***	−9.91e-07
	(5.39e-07)	(3.57e-07)	(2.43e-07)	(1.45e-06)
OGS	0.00531***	0.00392***	0.00410***	−0.000875***
	(0.00121)	(0.000465)	(0.000763)	(9.17e-05)
Constant	20.28***	1.152***	6.204***	9.294***
	(0.777)	(0.103)	(0.269)	(0.0357)
Observations	109	109	107	66
R-squared	0.923	0.865	0.849	0.887

*NOE, means Nitrous oxide emissions in terms of % change from 1990; NOEM, means Nitrous oxide emissions in terms of thousand metric tons of CO2 equivalent; ME, means Methane emissions measured through % change from the year 1990; MEK, means Methane emissions observed through kt of CO2 equivalent during the study period; TGSE, means total greenhouse gas emissions as observed through % change from 1990; TGEK, indicates the total amount of greenhouse gas emissions (kt of CO2 equivalent); OGS, reflects the other greenhouse gas emissions (% change from 1990); AGRMEX, indicates Agricultural raw materials exports; AGRMIM, indicates Agricultural raw materials imports (% of merchandise imports); AFFVAD, indicates the amount of Agriculture, forestry, and fishing, value added measured through % of GDP; LAFFFVAUSD, reflects log value of Agriculture, forestry, and fishing, value added as current US$, robust standard errors in parentheses,* ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

and TGSE is highly significant and negative, provided that there is an adverse and significant impact of MEK and TGSE on Agricultural raw materials exports (% of merchandise exports). Finally, the findings under **Table 2** observed highly significant impact from OGS which indicates a direct association between OGS and first dependent variable of the study. The value of overall coefficient of determination in the first dependent variable is 92.3 percent, reflecting a higher level of variation in the agriculture export due to climate extreme indicators.

For the second dependent variables, the study findings show that Agricultural raw materials imports (% of merchandise imports) is positively and significantly determined by NOE, MEK, and OGS, while significant and negative impact is observed by NOEM and TGSE, respectively. This would claim that for mixed trend in Agricultural raw materials imports (% of merchandise imports) is found by the selected explanatory variables of the study. For the third dependent variable, Agriculture, forestry, and fishing, value added (% of GDP), our study output confirms that NOE, MEK, and OGS are positively determining it, whereas NOEM, ME < and TGEK are observed as an adverse determinant. This would also justify the claim that there is a direct as well as indirect impact of climate extreme dynamics on the Agriculture, forestry, and fishing, value added (% of GDP) in panel economies. Finally, the study results under fourth multiple regression model are observed for the Agriculture, forestry, and fishing, value added (current US$) where the positive and significant impact from MEK, OGS and TGSE is observed. However, the impact from MEK and TGSE is observed as positively significant for the fourth dependent variable of the study.

Table 3 considers the output for the regression results as observed with the help of least square dummy variable model, where the effect of individuals entities is added and presented. The findings confirms that NOE has its negative influence on the first dependent variable; Nitrous oxide emissions (% change from 1990). This would indicate that higher such type of emission is causing lower level of Agricultural raw materials exports (% of merchandise exports). However, the impact from NOEM on Agricultural raw materials exports (% of merchandise exports) is positively significant at 1 percent with the lowest value of standard error and higher level of confidence; 99 percent.

However, the influence from MEK and ME is observed as insignificant under full sample output. Additionally, our study findings through dummy variable model indicate that TGSE is negatively and significantly linked with the Agricultural raw materials exports (% of merchandise exports). Furthermore, the influence from all four dummy variables for the selected

TABLE 3 | Climate extreme and agriculture dynamics under LSDV estimation.

Variables	Model 1	Model 2	Model 3	Model 4
NOE	−0.0965*	0.0498***	0.0562	−0.00406
	(0.0514)	(0.0157)	(0.0414)	(0.00509)
NOEM	0.000341***	−6.51e-05*	−1.12e-05	1.75e-05
	(0.000105)	(3.22e-05)	(8.34e-05)	(8.84e-06)
ME	−0.198	0.231***	−0.0565	0.0612***
	(0.0841)	(0.0258)	(0.0728)	(0.0106)
MEK	0.000141	−0.000276***	1.65e-05	−6.31e-05***
	(0.000102)	(3.11e-05)	(8.37e-05)	(1.11e-05)
TGSE	−0.139***	−0.0704***	−0.0409**	0.000454
	(0.0318)	(0.00974)	(0.0259)	(0.00487)
TGEK	1.75e-05**	6.13e-06***	4.21e-06	4.61e-06***
	(6.45e-06)	(1.98e-06)	(5.47e-06)	(1.17e-06)
OGS	0.00410***	0.00242***	0.00294**	−0.00187***
	(0.00127)	(0.000390)	(0.000995)	(0.000139)
_lid_2	−34.77***	19.63***	−1.632	4.667***
	(6.171)	(1.890)	(5.229)	(0.727)
_lid_3	−42.64***	22.55***	−5.173	4.391***
	(6.891)	(2.111)	(5.915)	(0.798)
_lid_4^	−47.35***	8.876***	−11.60	—
	(7.701)	(2.359)	(7.166)	
_lid_5^	−41.08***	17.76***	−3.957	—
	(5.794)	(1.775)	(5.095)	
Constant	8.852***	7.723***	6.135***	11.00***
	(2.191)	(0.671)	(1.826)	(0.259)
Observations	109	109	107	66
R-squared	0.961	0.948	0.860	0.941

*NOE, means Nitrous oxide emissions in terms of % change from 1990; NOEM, means Nitrous oxide emissions in terms of thousand metric tons of CO2 equivalent; ME, means Methane emissions measured through % change from the year 1990; MEK, means Methane emissions observed through kt of CO2 equivalent during the study period; TGSE, means total greenhouse gas emissions as observed through % change from 1990; TGEK, indicates the total amount of greenhouse gas emissions (kt of CO2 equivalent); OGS, reflects the other greenhouse gas emissions (% change from 1990); AGRMEX, indicates Agricultural raw materials exports; AGRMIM, indicates Agricultural raw materials imports (% of merchandise imports); AFFVAD, indicates the amount of Agriculture, forestry, and fishing, value added measured through % of GDP; LAFFFVAUSD, reflects log value of Agriculture, forestry, and fishing, value added as current US$, robust standard errors in parentheses,* ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$, *^the impact from lid4, and lid5 is omitted due to very minor effect.*

TABLE 4 | Climate extreme and agriculture dynamics under fixed effect estimation.

Variables	Fixed effect	Fixed effect	Fixed effect	Fixed effect
	Model 1	Model 2	Model 3	Model 4
NOE	−0.0965*	0.0498***	0.0562	−0.00406
	(0.0514)	(0.0157)	(0.0414)	(0.00509)
NOEM	0.000341***	−6.51e-05*	−1.12e-05	1.75e-05
	(0.000105)	(3.22e-05)	(8.34e-05)	(8.84e-06)
ME	−0.198	0.231***	−0.0565	0.0612***
	(0.0841)	(0.0258)	(0.0728)	(0.0106)
MEK	0.000141	−0.000276***	1.65e-05	−6.31e-05***
	(0.000102)	(3.11e-05)	(8.37e-05)	(1.11e-05)
TGSE	−0.139***	−0.0704***	−0.0409**	0.000454
	(0.0318)	(0.00974)	(0.0259)	(0.00487)
TGEK	1.75e-05**	6.13e-06***	4.21e-06	4.61e-06***
	(6.45e-06)	(1.98e-06)	(5.47e-06)	(1.17e-06)
OGS	0.00410***	0.00242***	0.00294**	−0.00187***
	(0.00127)	(0.000390)	(0.000995)	(0.000139)
Constant	−24.30***	21.43***	1.862	14.01***
	(6.510)	(1.994)	(5.798)	(0.758)
Observations	109	109	107	66
R-squared	0.691	0.878	0.321	0.803
Number of ids	5	5	5	3

*NOE, means Nitrous oxide emissions in terms of % change from 1990; NOEM, means Nitrous oxide emissions in terms of thousand metric tons of CO2 equivalent; ME, means Methane emissions measured through % change from the year 1990; MEK, means Methane emissions observed through kt of CO2 equivalent during the study period; TGSE, means total greenhouse gas emissions as observed through % change from 1990; TGEK, indicates the total amount of greenhouse gas emissions (kt of CO2 equivalent); OGS, reflects the other greenhouse gas emissions (% change from 1990); AGRMEX, indicates Agricultural raw materials exports; AGRMIM, indicates Agricultural raw materials imports (% of merchandise imports); AFFVAD, indicates the amount of Agriculture, forestry, and fishing, value added measured through % of GDP; LAFFFVAUSD, reflects log value of Agriculture, forestry, and fishing, value added as current US$, robust standard errors in parentheses,* ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

agriculture economies is found to be negatively significant which implies that there is a significant need to control the effect of such heterogeneity while observing the association between climate threatening factors and agriculture key indicators. In addition, the influence from the climate threating factors on the second indicator of agriculture industry of all five economies is also presented under **Table 3**. The findings confirm a direct association between NOE and Agricultural raw materials imports (% of merchandise imports) which specifies that higher NOE is leading to higher level of agriculture import. Meanwhile, the impact of NOEM on the Agricultural raw materials imports (% of merchandise imports) is positively significant at 10 percent. In addition, our study findings confirm the fact that MEK and TGSE are also showing their negative impact on the Agricultural raw materials imports (% of merchandise imports). However, TGEK and OGS are observed as a positive indicator for higher amount of agriculture import in all the selected economies. Furthermore, our study findings have confirmed that dummy variables have their significant and positive impact on the agriculture import. These findings have confirmed the idea that higher climate changing elements like carbon emission is leading towards lower amount of agriculture export and at the same time, causing an upward shift for the agriculture imports.

In addition, the findings under Model 3 (**Table 3**) specifies that only the factors like Total greenhouse gas emissions (% change from 1990) and other greenhouse gas emissions (% change from 1990) are observed as significant determinants of Agriculture, forestry, and fishing, value added (% of GDP). This would justify the argument that there is a mixed effect from the environmental threatening dynamics on the agriculture industry of top five agro-economies. Furthermore, the influence on the agriculture, forestry, and fishing, value added (current US$) as measured through log values have provided the evidence that there is a negative impact from MEK and OGS. However, we have a positive effect of TGEK on Agriculture, forestry, and fishing, value added (current US$).

Table 4 predicts the relationship between agriculture factors and climate extreme dynamics as measured through fixed effect regression coefficients. The findings have confirmed that NOE has its negative and significant impact while NOEM is positively and significant linked with it. This would justify the claim that there is a mixed trend between the Nitrous oxide emissions (% change from 1990), Nitrous oxide emissions (thousand metric tons of CO2 equivalent) and Agricultural raw materials exports (% of merchandise exports). It means that higher NOE is adversely affecting the agriculture export while NOEM is causing a direct change in it. However, ME has provided the evidence for the negative but insignificant influence on Agricultural raw materials exports (% of merchandise exports).

In addition, the findings under Model through fixed effect regression estimator also indicates that there is a negative and significant impact from MEK and TGSE while positive and highly significant impact is observed through TGEK. This would again claim that these environmental dimensions have also shown a mixed effect on the Agricultural raw materials imports (% of merchandise imports). Meanwhile, OGS has also provided the evidence that there is a positive and significant impact on the value of Agricultural raw materials imports (% of merchandise imports).

Under third regression model, our study examines the influence of selected environmental variables on Agriculture, forestry, and fishing, value added (% of GDP). The results have confirmed that there is a negative and significant impact of Total greenhouse gas emissions (% change from 1990) on the stated value of Agriculture, forestry, and fishing, value added (% of GDP). This means that for every single unit increase in the value of TGSE, there an effect of −0.0472 on the value of Agriculture, forestry, and fishing, value added (% of GDP). Meanwhile, OGS has shown a positively significant impact on the value of Agriculture, forestry, and fishing, value added (% of GDP).

Furthermore, Model 4 provides the evidence for examining the influence from all set of explanatory variables on the fourth dimension of agriculture sector among selected economies. The results confirm that ME and TGEK have their significantly positive impact on Agriculture, forestry, and fishing, value added (current US$), whereas the influence from MEK and OGS is highly significant and negative. Finally, the model fitness specifies that there is a higher level of variation in the key dependent variables, except for Agriculture, forestry, and fishing, value added (% of GDP), where the total value of explained variation is only 32.1 percent.

TABLE 5 | Climate extreme and agriculture dynamics under random effect estimation.

Variables	Random effect	Random effect	Random effect	Random effect
	Model 1	Model 2	Model 3	Model 24
NOE	−0.247***	0.0684***	0.0846***	−0.00682
	(0.0189)	(0.00661)	(0.0112)	(0.00681)
NOEM	0.000535***	−5.23e-05***	-0.000097***	5.14e-06
	(4.39e-05)	(1.54e-05)	(2.49e-05)	(1.14e-05)
ME	0.212***	0.0387***	-0.0631***	−0.00724*
	(0.0188)	(0.00658)	(0.0114)	(0.00310)
MEK	−0.000322***	2.67e-05***	5.91e-05***	7.31e-06***
	(2.01e-05)	(7.03e-06)	(1.13e-05)	(1.97e-06)
TGSE	−0.0413**	−0.0807***	−0.0363***	0.0141**
	(0.0175)	(0.00613)	(0.0105)	(0.00551)
TGEK	−1.51e-05***	4.16e-06***	−3.71e-06***	−9.91e-07
	(6.41e-07)	(2.24e-07)	(4.18e-07)	(1.11e-06)
OGS	0.00531***	0.00392***	0.00410***	−0.000875***
	(0.00133)	(0.000466)	(0.000767)	(0.000109)
Constant	20.28***	1.152***	6.204***	9.294***
	(0.519)	(0.181)	(0.299)	(0.0437)
Observations	109	109	107	66
Number of ids	5	5	5	3

*NOE, means Nitrous oxide emissions in terms of % change from 1990; NOEM, means Nitrous oxide emissions in terms of thousand metric tons of CO2 equivalent; ME, means Methane emissions measured through % change from the year 1990; MEK, means Methane emissions observed through kt of CO2 equivalent during the study period; TGSE, means total greenhouse gas emissions as observed through % change from 1990; TGEK, indicates the total amount of greenhouse gas emissions (kt of CO2 equivalent); OGS, reflects the other greenhouse gas emissions (% change from 1990); AGRMEX, indicates Agricultural raw materials exports; AGRMIM, indicates Agricultural raw materials imports (% of merchandise imports); AFFVAD, indicates the amount of Agriculture, forestry, and fishing, value added measured through % of GDP; LAFFFVAUSD, reflects log value of Agriculture, forestry, and fishing, value added as current US$, robust standard errors in parentheses, ***p < 0.01, **p < 0.05, *p < 0.1.*

Finally, **Table 5** confirms the regression results as measured through random effect estimation. It is observed that NOE is found to be significant indicator among all three dependent variables, however, its impact on Agriculture, forestry, and fishing, value added (current US$) is negatively insignificant. Meanwhile, Nitrous oxide emissions (thousand metric tons of CO2 equivalent) has explained the fact that there is a direct impact on Agricultural raw materials exports (% of merchandise exports), while negative and significant impact on AG, RMEX and AGRMIM, respectively. In addition, Methane emissions (% change from 1990) or ME confirms its positive impact on agriculture export and import while negative influence on Agriculture, forestry, and fishing, value added (% of GDP, and log of current USD). Furthermore, the study findings under random effect output also confirms some mixed output where MEK is negatively impacting on the agriculture export and at the same time, it is showing its adverse impact on the value of agriculture import. Meanwhile, TGEK is showing its similar impact for lowering down the export and pushing more pressure towards agriculture import among the member states. Finally, OG is observed as positively significant determinant for all four dependent variables of the study.

CONCLUSION AND POLICY IMPLICATIONS

This study describes several outputs while determining the economic output of changing climate predicted through climate change models on agriculture among top five agro-based economies. The study has provided some mixed results. For example, it is found that agriculture export in the selected economies is negatively affected by some of the climate change dynamics based on climate change models, whereas the level of agriculture import is positively and significantly affected by some of the climate change indicators. Meanwhile, the impact on Agriculture, forestry, and fishing, value added (% of GDP, and current USD) has also provides some mixed evidence. The study findings have provided the evidence that both the environmental factors and key agriculture indicators are closely linked to each other. Meanwhile, mixed evidence further confirms that both positive and negative impact from environmental threats is here specifically among the top agriculture economies of the world. The empirical analysis under current study has explored the climate sensitivity that is predicted through climate change models for the agriculture sector. For this purpose, in order to control the adverse impact of changing climate as measured through set of dimensions, it is very important to develop some strategic polices and tactical planning. furthermore, it is also important to note that different climate dynamics have their differential impact on the agriculture sector. This impact has suggested that such impact will greatly depend on the local climate of selected economies in the upcoming years. However, putting some significant efforts can lower down the adverse impact of climate factors on the agriculture sector. For example, it is suggested that government in the selected economies need to work on minimizing the impact of carbon emission on both export and import factors. Additionally, it is suggested that all the targeted economies should immediately work to shift towards some renewable energy sources which can create lower environmental impact. This effort would result in stability in the climate and in return there will be better agriculture output for more export and lower import as well. Furthermore, the government departments specifically those responsible for the changing climate are highly suggested to review the current study findings while developing any related policies. However, the economic outcome of climate change as observed in this research would also support to various economists as well. Besides, researchers and academic concerns in the field of climate change and agriculture economy may also get significant benefit from the findings under present study. However, some limitations are also associated with the current study. Firstly, this study considers the limited number of explanatory variables for reflecting the changing climate trends among top five agriculture economies of the world. However, there are still range of other factors which can be observed in the future studies to examine their influence on the selected indicators of agriculture industry. Secondly, this study has applied traditional panel models where no implication is observed for the dynamic panel methods like Generalized methods of Moments or GMM. Thirdly, this study has not provided any evidence for the cross-country analysis. Fourthly, this study has limited time span along with missing examination of both short run and long as well. Future studies may address these limitations for better implication in both theoretical and practical perspective.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

All authors contributed equally. ll design the main idea. AM drafted the writing. SC collected the data and anaylzed. GA and AD review and modified the manuscript and OA review the manuscript and NA supervise it.

ACKNOWLEDGMENTS

The authors would like to extend their sincere appreciation to the acknowledgment; research supporting project (No. RSP-2022/95, King Saud University, Riyadh, Saudi Arabia).

REFERENCES

Adams, R., Hurd, B., Lenhart, S., and Leary, N. (1998). Effects of Global Climate Change on World Agriculture: an Interpretive Review. *Clim. Res.* 11 (1), 19–30. doi:10.3354/cr011019

Aleixandre-Benavent, R., Aleixandre-Tudó, J. L., Castelló-Cogollos, L., and Aleixandre, J. L. (2017). Trends in Scientific Research on Climate Change in Agriculture and Forestry Subject Areas (2005-2014). *J. Clean. Prod.* 147, 406–418. doi:10.1016/j.jclepro.2017.01.112

Ali, S., Liu, Y., Ishaq, M., Shah, T., Abdullah, A., Ilyas, A., et al. (2017). Climate Change and its Impact on the Yield of Major Food Crops: Evidence from Pakistan. *Foods* 6 (6), 39. doi:10.3390/foods6060039

Amen, R., Hameed, J., Albashar, G., Kamran, H. W., Shah, M. U. H., Zaman, K. U., et al. (2020). Modeling the Higher Heating Value of Municipal Solid Waste for Assessment of Waste-To-Energy Potential: A Sustainable Case Study. *J. Clean. Prod.* 287 (4), 125575. doi:10.1016/j.jclepro.2020.125575

Aydinalp, C., and Cresser, M. S. (2008). The Effects of Global Climate Change on Agriculture. *American-Eurasian J. Agric. Environ. Sci.* 3 (5), 672–676.

Bombelli, A., Di Paola, A., Chiriacò, M. V., Perugini, L., Castaldi, S., and Valentini, R. (2019). "Climate Change, Sustainable Agriculture and Food Systems: The World after the Paris Agreement," in *Achieving the Sustainable Development Goals through Sustainable Food Systems* (Springer), 25–34. doi:10.1007/978-3-030-23969-5_2

Bun, M., and Harrison, T. D. (2014). *OLS and IV Estimation of Regression Models Including Endogenous Interaction Terms*. London: University of Amsterdam discussion paper, 2.

Bun, M. J. G., and Harrison, T. D. (2019). OLS and IV Estimation of Regression Models Including Endogenous Interaction Terms. *Econometric Rev.* 38 (7), 814–827. doi:10.1080/07474938.2018.1427486

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S. J., and Ringler, C. (2014). Climate Change and Agriculture: Impacts and Adaptation Options in South Africa. *Water Resour. Econ.* 5, 24–48. doi:10.1016/j.wre.2014.03.001

Calzadilla, A., Zhu, T., Rehdanz, K., Tol, R. S. J., and Ringler, C. (2013). Economywide Impacts of Climate Change on Agriculture in Sub-saharan Africa. *Ecol. Econ.* 93, 150–165. doi:10.1016/j.ecolecon.2013.05.006

Chen, S., Chen, X., and Xu, J. (2016). Impacts of Climate Change on Agriculture: Evidence from China. *J. Environ. Econ. Manag.* 76, 105–124. doi:10.1016/j.jeem.2015.01.005

Chien, F., Kamran, H. W., Albashar, G., and Iqbal, W. (2020). Dynamic Planning, Conversion, and Management Strategy of Different Renewable Energy Sources: A Sustainable Solution for Severe Energy Crises in Emerging Economies. *Int. J. Hydrogen Energ.* 46. doi:10.1016/j.ijhydene.2020.12.004

Dar, A. A., Chen, J., Shad, A., Pan, X., Yao, J., Bin-Jumah, M., et al. (2020). A Combined Experimental and Computational Study on the Oxidative Degradation of Bromophenols by Fe(VI) and the Formation of Self-Coupling Products. *Environ. Pollut.* 258, 113678. doi:10.1016/j.envpol.2019.113678

Dar, A. A., Pan, B., Qin, J., Zhu, Q., Lichtfouse, E., Usman, M., et al. (2021a). A Review on Sustainable Ferrate Oxidation: Reaction Chemistry, Mechanisms and Applications to Eliminate Micro Pollutant (Pharmaceuticals) in Wastewater. *Environ. Pollut.* 290 (275), 117957. doi:10.1016/j.envpol.2021.117957

Dar, A. A., Shakoor, A., Niazi, N. K., Tufail, M. A., Syed, J. A. S., Sarfraz, M., et al. (2021b). A Meta-Analysis of Photocatalytic Performance and Efficiency of Bismuth Oxide (BiO2_x). *J. Clean. Prod.* 322, 129070. doi:10.1016/j.jclepro.2021.129070

Foster, G., and Kalenkoski, C. M. (2013). Tobit or OLS? an Empirical Evaluation under Different Diary Window Lengths. *Appl. Econ.* 45 (20), 2994–3010. doi:10.1080/00036846.2012.690852

Husnain, M. I. U., Subramanian, A., and Haider, A. (2018). Robustness of Geography as an Instrument to Assess Impact of Climate Change on Agriculture. *Int. J. Clim. Change Strateg. Manag.* 10 (5), 654–669. doi:10.1108/ijccsm-03-2017-0049

Ignaciuk, A., and Mason-D'Croz, D. (2014). *Modelling Adaptation to Climate Change in Agriculture*.

Islam, M. T., and Nursey-Bray, M. (2017). Adaptation to Climate Change in Agriculture in Bangladesh: The Role of Formal Institutions. *J. Environ. Manag.* 200, 347–358. doi:10.1016/j.jenvman.2017.05.092

Kamran, H. W., Haseeb, M., Nguyen, T. T., and Nguyen, V. (2020). *Climate Change and Bank Stability: The Moderating Role of green Financing and Renewable Energy Consumption in ASEAN*.

Karimi, V., Karami, E., and Keshavarz, M. (2018). Climate Change and Agriculture: Impacts and Adaptive Responses in Iran. *J. Integr. Agric.* 17 (1), 1–15. doi:10.1016/s2095-3119(17)61794-5

Kumar, P., Tokas, J., Kumar, N., Lal, M., and Singal, H. (2018). Climate Change Consequences and its Impact on Agriculture and Food Security. *Int. J. Chem. Stud.* 6 (6), 124–133.

Kumari, S., George, S. G., Meshram, M. R., Esther, D. B., and Kumar, P. (2020). A Review on Climate Change and its Impact on Agriculture in India. *Curr. J. Appl. Sci. Techn.* 39, 58–74. doi:10.9734/cjast/2020/v39i4431152

Lehtonen, H. S., Aakkula, J., Fronzek, S., Helin, J., Hildén, M., Huttunen, S., et al. (2021). Shared Socioeconomic Pathways for Climate Change Research in

Finland: Co-developing Extended SSP Narratives for Agriculture. *Reg. Environ. Change* 21 (1), 1–16. doi:10.1007/s10113-020-01734-2

Ma, T., Zhou, C., Pei, T., Haynie, S., and Fan, J. (2012). Quantitative Estimation of Urbanization Dynamics Using Time Series of DMSP/OLS Nighttime Light Data: A Comparative Case Study from China's Cities. *Remote Sensing Environ.* 124, 99–107. doi:10.1016/j.rse.2012.04.018

Mahasenan, N., Smith, S., and Humphreys, K. (2003). The Cement Industry and Global Climate Change: Current and Potential Future Cement Industry CO2 Emissions. in Paper presented at the Greenhouse Gas Control Technologies-6th International Conference.

Mahato, A. (2014). Climate Change and its Impact on Agriculture. *Int. J. Scientific Res. Publications* 4 (4), 1–6.

Maia, A. G., Miyamoto, B. C. B., and Garcia, J. R. (2018). Climate Change and Agriculture: Do Environmental Preservation and Ecosystem Services Matter. *Ecol. Econ.* 152, 27–39. doi:10.1016/j.ecolecon.2018.05.013

Malik, A., Mor, V. S., Tokas, J., Punia, H., Malik, S., Malik, K., et al. (2021). Biostimulant-Treated Seedlings under Sustainable Agriculture: A Global Perspective Facing Climate Change. *Agronomy* 11 (1), 14. doi:10.3390/agronomy11010014

Mendelsohn, R. (2008). The Impact of Climate Change on Agriculture in Developing Countries. *J. Nat. Resour. Pol. Res.* 1 (1), 5–19. doi:10.1080/19390450802495882

Mishra, D., and Sahu, N. C. (2014). Economic Impact of Climate Change on Agriculture Sector of Coastal Odisha. *APCBEE Proced.* 10, 241–245. doi:10.1016/j.apcbee.2014.10.046

Nawaz, M. A., Hussain, M. S., Kamran, H. W., Ehsanullah, S., Maheen, R., and Shair, F. (2020a). Trilemma Association of Energy Consumption, Carbon Emission, and Economic Growth of BRICS and OECD Regions: Quantile Regression Estimation. *Environ. Sci. Pollut. Res. Int.* 28 (13), 16014–16028. doi:10.1007/s11356-020-11823-8

Nawaz, M. A., Seshadri, U., Kumar, P., Aqdas, R., Patwary, A. K., and Riaz, M. (2020b). Nexus between green Finance and Climate Change Mitigation in N-11 and BRICS Countries: Empirical Estimation through Difference in Differences (DID) Approach. *Environ. Sci. Pollut. Res. Int.* 28, 6504–6519. doi:10.1007/s11356-020-10920-y

Ofoegbu, C., and New, M. (2021). The Role of Farmers and Organizational Networks in Climate Information Communication: the Case of Ghana. *Int. J. Clim. Change Strateg. Manag.* 13 (1), 19–34. doi:10.1108/ijccsm-04-2020-0030

Ohlson, J. A., and Kim, S. (2015). Linear Valuation without OLS: the Theil-Sen Estimation Approach. *Rev. Account. Stud.* 20 (1), 395–435. doi:10.1007/s11142-014-9300-0

Ramanathan, V., and Feng, Y. (2009). Air Pollution, Greenhouse Gases and Climate Change: Global and Regional Perspectives. *Atmos. Environ.* 43 (1), 37–50. doi:10.1016/j.atmosenv.2008.09.063

Salvo, D., Begalli, D., and Signorello, G. (2013). Measuring the Effect of Climate Change on Agriculture: A Literature Review of Analytical Models. *J. Dev. Agric. Econ.* 5 (12), 499–509. doi:10.5897/jdae2013.0519

Singh, P., Vaidya, M. K., and Pathania, K. (2021). *Economic Impact of Climate Change on Agriculture: Present, Past and Future*.

Sun, H., Awan, R. U., Nawaz, M. A., Mohsin, M., Rasheed, A. K., and Iqbal, N. (2020). Assessing the Socio-Economic Viability of Solar Commercialization and Electrification in South Asian Countries. *Environ. Develop. Sustainability* 23, 1–23. doi:10.1007/s10668-020-01038-9

Walthall, C. L., Anderson, C. J., Baumgard, L. H., Takle, E., and Wright-Morton, L. (2013). *Climate Change and Agriculture in the United States: Effects and Adaptation.*

Zhang, P., Zhang, J., and Chen, M. (2017). Economic Impacts of Climate Change on Agriculture: The Importance of Additional Climatic Variables Other Than Temperature and Precipitation. *J. Environ. Econ. Manag.* 83, 8–31. doi:10.1016/j.jeem.2016.12.001

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.