Journal of Agriculture

Effect of Climate Change on Agricultural Productivity in Japan

Tadashi Huang Rehman, Dr. Anwar Kazuko Shah & Saburo Jatoi Hussain

ISSN: 2616-8456

Stratford Peer Reviewed Journals and Book Publishing
Journal of Agriculture
Volume 6||Issue 1||Page 13-23||June||2022|
Email: info@stratfordjournals.org ISSN: 2616-8456

Effect of Climate Change on Agricultural Productivity in Japan

[1*]Tadashi Huang Rehman, [2]Dr. Anwar Kazuko Shah & [3]Saburo Jatoi Hussain
[123]University of Tsukuba

Email of the corresponding author: tadashiHuangehman@gmail.com

How to cite this article: **Rehman, T., H., Shah, A., K. & Hussain, S., J. (2022). Effect of Climate Change on Agricultural Productivity in Japan. *Journal of Agriculture*, 6(1), 13-23.** https://doi.org/10.53819/81018102t5075

Abstract

The study sought to examine the effect of climate change on agricultural productivity in Japan. The study adopted the cross-section research design. Questionnaires were used to collect the data. The respondents included farmers and officials in Japan's Ministry of Agriculture, Forestry and Fisheries. The study indicated the negative and significant correlation between agricultural productivity and climate change. Climate change was found to be satisfactory in explaining agricultural productivity in Japan. The results indicated that climate change is a good predictor of agricultural productivity. The regression results showed that climate change is negatively and significantly related to agricultural productivity. The results implied that when the climate change deteriorates by one unit, the agricultural productivity will reduce by 0.327 units holding other factors constant. The effect of climate change is frequent wildfires, more extended periods of drought in some regions and an increase in the number, duration and intensity of tropical storms. The study recommended there is a need to focus on planet-friendly investments. Individuals can spur change through savings and investments by choosing financial institutions that do not invest in carbon-polluting industries. The government needs to accomplish sensitization program awareness on cause, influence, reduction and adjustment to environmental change. The government needs to additionally urge the adoption of smart agriculture where farmers do not count on rain feed agriculture but on scientific agriculture. It should provide farmers with drought-resistant seeds and livestock to improve production and ensure food security in Japan. Technological development can decrease the unfavorable effects of weather irregularity and might affect global adaptation efforts favoring various nations. There should be an emphasis on more tree planting in the country.

Keywords: *Climate Change, Agricultural Productivity, Japan*

1.0 Introduction

As Japan's climate changes and weather condition patterns are influenced, there are high chances that more intense and repeatedly severe weather conditions, like tornados, droughts, and flooding, will likely affect Japan's economy. Adverse weather conditions like flooding, severe heat, and drought have led to soil degradation, which causes reduced returns from crops. A decrease in agricultural productivity lets the farmers down and might lead to changes in income sources, particularly for the residents (Hussain, Qamar, Adhikari, Hunzai, Rehman & Bano, 2021). Rice is the essential crop in Japan and is grown on the best agricultural land. Various other crops planted in Japan consist of soybeans, wheat, barley, and a massive variety of vegetables and fruit. Bastin, Clark, Elliott, Hart, Van Den Hoogen, Hordijk and Crowther (2019) argued that climate is a combination of complex weather conditions averaged over a significant area of the earth. Climate change is described as changes beyond the average atmospheric condition, which are brought about by natural factors like the earth's rotation, volcanic eruptions and crustal activities, and man-made aspects like an increase in greenhouse gases and aerosol (Letcher, 2021). Climate change by global warming, which refers to the typical rise in global temperature level, has become a big problem that will cause adverse global changes in the future. It is undeniable that global warming has a significant effect on the earth and it is likely that the rise in greenhouse gas discharge by anthropogenic activities has created global warming.

Climate change refers to a change in the state of the environment that can be discovered by changes in the mean or irregularity of its properties that persist for more extended periods (Thomas, Baptiste, Martyr-Koller, Pringle & Rhiney, 2020). Climatic factors like light, water, rainfall, temperature level, air, moisture, and wind also influence agriculture. Like other abiotic components, environmental factors like soil and topography usually affect how plants grow and develop. Temperatures which are extremely hot damage fruits in different methods, like sunburn or discolouration. Products of animals are also in danger, with climate change reducing the quantity of usable cow's milk along with beef, pork and chicken. Ye, Jiang, Liu, Zheng and Zhou (2021) noted that global warming had recently been a problem. The effects of future environmental change on several sectors like agriculture, forestry, water, power, environment, and health have recently been controversial. Warming has been on an increasing trend since the 1980s.

The agricultural sector is the most vulnerable to changes in climate (Parker, Bourgoin, Martinez-Valle & Läderach, 2019). Regardless of the advancement in technology in the second half of the 20th century, consisting of the green revolution, weather conditions and climate are still vital factors determining farming production worldwide. The anticipated changes in temperatures and rainfall patterns, together with their related influence on water availability, pests, diseases, and severe climate, are all likely to significantly impact farming productivity capacity. Zhang, You, Mao, Chen and Ye (2019) noted that climate change recommends that even though global crop production might be improved slightly by global warming in the short-term (before 2030), it will eventually turn negative in the long term. Additionally, the effect of climate change on agricultural productivity is unlikely to be uniformly distributed throughout the regions (Skendžić, Zovko, Živković, Lešić & Lemić, 2021). Low latitude and developing nations are anticipated to experience much more from the agricultural effects of global warming, reflecting their deprived geographic area, more significant farming share in their economy, and limited capability to cope with climate change. Crop production in high latitude areas will usually benefit from climate change. In a recent worldwide comprehensive estimate for over 99 nations, it is forecasted that worldwide farming productivity would decrease by 16.4% in the 2070s if global warming continues unrelenting, with developing nations facing a disproportionately more considerable decrease of 20.4%.

Agriculture depends highly on climate issues, like temperature levels, solar radiation, and precipitation (Hussain, Huang, Huang, Ahmad, Nanda, Anwar & Zhang, 2020). Future climate change will influence agricultural productivity and might make food products vulnerable. Farming in nations at higher latitudes would likely gain from a moderate level of warming (2-3°C); however, that little climate change in exotic areas would decrease yields. Japan lies at a relatively high latitude, so that Japanese rice production might gain from future climate change (Oka, Mizutani & Ashina, 2020). However, an increased return does not necessarily imply an economic benefit. To gauge the economic influence of climate change, we are required to assess changes in quantity and price while considering market conditions. A detailed evaluation of the influence of climate change on agriculture is critical for making policy decisions and from an academic interest viewpoint.

Farmers are frequently flexible in coping with the climate and season-to-season irregularity; there is, however, a high degree of adaptation to the local climate in the form of advanced facilities, regional farming practice and personal experience (Gruda, Bisbis & Tanny, 2019). Climate change can be anticipated to influence farming, possibly putting at risk developed factors of farming systems and providing opportunities for renovations. Severe drought conditions, regularly happening as a result of climate change, worsen the productivity of crops by triggering vitamins and mineral immobilization and salt build-up in soils, making them completely dry, undesirable, saline and finally sterile. Those barren areas become non-arable with time and are eventually deserted by farmers, bringing about economic losses and social problems (Shah, Nazari, Antar, Msimbira, Naamala, Lyu & Smith, 2021). Anticipated climate variations are not restricted to just an increase in drought conditions. The environment is constantly changing, and the signals showing that changes are taking place can be examined over various temporal and spatial ranges.

2.0 Literature Review

Miles-Novelo and Anderson (2019) reported that global warming had been a recent concern in numerous aspects since it has risen since the 1980s. Climate change may be the main issue for humanity since it impacts many sectors and various aspects of human life. The negative effects of environmental change on the agricultural industry will be particularly hazardous because agriculture is directly associated to food security and human life. The research examines the impact of environmental change on farming productivity in 10 Asian nations between 2000 and 2012. The research approximates a nation-level fixed impact panel model for faring production utilizing seasonal climate and other input factors. The findings reveal that higher temperatures and more rainfalls in summertime improve farming production while loss of temperature level is dangerous in South and Southeast Asia. On the other hand, the total rise in annual temperature reduces faring production in Asian nations.

Arora (2019) argued that taking advantage of the most current worldwide approximations of the effects of climate change on farming production, the study evaluates the economic impacts of climate change in Japan. The findings advised that the aggregate effects of agricultural damages led by climate change on the worldwide economy are average. Nevertheless, the improper distribution of production losses worldwide would cause substantial structural changes in global farming production and trade, eventually leaving the growing nation as a total loser. With the projected decreasing agricultural share in the economy, a decrease in farming production will have little but non-negligible adverse effects on Japan's economic output. Nevertheless, the anticipated rise of crop import reliance in the coming years would make most Japanese regions endure more well-being losses via worn-out terms of trade. According to the nation's economic structure, the unfavourable impacts are anticipated to be less for Singapore and Malaysia but higher for the Philippines, Indonesia, Thailand, and Vietnam. To handle the possible agricultural damages coming from the projected changes in climate, the area should focus on reversing its present trend of decreasing farming production.

Jatoi, Mubeen, Ahmad, Cheema, Lin and Hashmi (2021) researched the influence of global-warming-induced climate change on Thailand's agricultural productivity by using panel data. Initially, panel information is developed, incorporating time-series information from 2000 to 2015 for a cross-section of 10 regions in Thailand. We performed a fixed time series data evaluation, utilizing a function for farming products integrating labor and three weather factors (temperature level, solar radiation, and rainfall). From the estimated outcomes of the production function, The study chose the productivity function with the previously mentioned labor and weather factors. We discovered that the increasing temperatures and rainfall and reduced solar radiation triggered by climate change had decreased rice farming while increasing temperature levels and rainfall have minimized the vegetable and potato farming in Thailand. Secondly, we performed dynamic time series data analysis, utilizing a productivity function for agricultural products, including labor, a one-period lagged output and three weather aspects. According to the estimated outcomes of the dynamic time-series information model, we chose the productivity function for farming products utilizing just the labor and three climate aspects and discovered the exact outcomes for rice farming and vegetable and potato farming in Thailand. According to the projected outcomes of the static and dynamic-time series data models for variable mean yearly temperature, it is concluded that a rise of 2°C in mean yearly temperature would lower rice farming by 6.4% in the short-run and 4.1% in the long-run, and veggies and potatoes farming by 6.2% and 9.5% in the short-run and long-run.

Khan, Gao, Abid and Shah (2021) discovered that future climate change will impact rice farming, but whether this change will be valuable or damaging is unclear. The current research analyzes the impact of environmental change on Pakistan rice farming, rice price, agriculture earnings, and regional economies by utilizing a recursive-dynamic regional computable general equilibrium (CGE) model related to crop development and crop-quality designs. Simulation outcomes show that future environmental change will improve general Pakistan rice farming nationally; however, the price of rice will undoubtedly reduce. Therefore, farming income will reduce, despite improved farming in the north and eastern Pakistan. Climate change will not make a profit for rice farmers in different areas. Nonetheless, the western area will benefit, regardless of the decline in farming, and the consumer surplus in many areas will rise. This takes place since rice need is inelastic and an improvement in production results in a significant decrease in price that exceeds the effects of environmental change on productivity. Therefore, the effects of environmental change are complex and vary by place, so a CGE model may give helpful information for considering policy counter-strategies.

Ortiz-Bobea, Ault, Carrillo, Chambers and Lobell (2021) noted that agricultural productivity is vulnerable to weather and thus directly influenced by climate change. Possible estimates of these environmental change influences call for mixed-use of climate, crop, and economic models. Findings from various researches differ significantly due to disparities in models, occasions, and information. The research becomes part of a collective effort to systematically incorporate these three sorts of designs. We concentrate on the economic element of the evaluation, evaluating exactly how eight international economic designs of farming represent endogenous reactions to 6 normal environment change circumstances generated by two climates and seven crop designs. This feedback consists of outputs, area, intake, and global trade modifications. The mean biophysical return impact without total CO2 fertilizer is a 20% decrease worldwide by 2060 relative to a circumstance with a changeless climate. Endogenous economic responses decrease return loss to 20%, increase the area of main crops by 21%, and lower intake by 5%. Farming production, cropland region, trade, and prices indicate the highest irregularity in response to environmental change and intake the most affordable. The sources of these distinctions consist of version structure and specification, specifically, model assumptions regarding ease of land-use conversion, rise, and trade. The research identifies where versions disagree on the relative responses to climate shocks and highlights study tasks required to enhance the depiction of farming adaptation reactions to environmental change.

A study by Banerjee, Cicowiez, Rios and de Lima (2021) examined the broad economic influence of Environment Change (EC) on farming and food security in 19 Latin America and the Caribbean (LAC) nations. Notably, we adhere to three networks whereby EC might influence farming and non-farming production: farming yields, labour efficiency in agriculture and economy-wide labor production. We execute the evaluation utilizing the Integrated Economic Environmental Model (IEEM) and databases for 19 LAC present with the OPEN IEEM System. Our evaluation determines those nations primarily impacted according to vital indicators (GDP), worldwide business, sectoral output, hardship, and discharges. Many nations face unfavourable influence on GDP, except the soybean farming nations, specifically Brazil, Argentina and Uruguay. It has been discovered that EC- generated crop production and labour efficiency changes impact nations differently. Nonetheless, the combined influence shows that Belize, Nicaragua, Guatemala, and Paraguay would fare the most awful. Early identification of these hardest struck nations can allow policymakers to pre-empt these impacts and start the design of adjustment approaches early on. Only Argentina, Chile, and Uruguay would experience small rises in discharges in greenhouse gas discharges.

Yalew, van Vliet, Gernaat, Ludwig, Miara, Park and Van Vuuren (2020) performed research concerning a variety of processes through which environmental change can potentially influence global-scale farming performance and present estimates of changes in pertinent atmospheric, hydrological and plant physical amounts from an environment model ensemble to illustrate vital places of unpredictability. A couple of global-scale evaluations have been carried out, and these are restricted in their ability to record the uncertainty in environment estimates and leave out possibly essential elements like extreme occasions and changes in diseases and pests. There is a lack of clarity on how climate change's influence on drought is best quantified from a farming viewpoint, with various metrics providing very different impressions of future threats. The dependence of some regional farming on remote rainfall, snowmelt and glaciers contribute to the intricacy. Indirect effects using sea-level surges, storms and other conditions have not been measured. Probably most seriously, there is high uncertainty in the degree to which the direct impacts of CO_2 increase on plant physiology will interact with environmental change in influencing productivity. Currently, the aggregate effects of environmental change on global-scale agricultural efficiency cannot be reliably evaluated.

Hussain, Huang, Huang, Ahmad, Nanda, Anwar and Zhang (2020) discovered that the recent pattern of rising temperature levels had affected agriculture in several ways, consisting of the farming and quality of rice, which is the staple food in Japan. These effects are forecasted to be much more constant and more serious under climate change estimates. The research intended to assess the impact of the projected rising temperatures because of climate change on the returns and quality of rice and to provide the local differences in the performance of relocating the transplanting date, which has been among the most effective adjustment actions, to avoid the unfavorable effects of heats on rice yield and high quality.

Emadodin, Corral, Reinsch and Taube (2021) articulated that environmental change is a global problem that has a higher influence on productivity via farming production, animal production, energy and tourism. Nations all over the globe have put good strategies in a position to battle or minimize its impacts. The research examined the effects of climate change on farming productivity in Germany. The research addressed two specific purposes; to determine the impact of environmental change on crop productivity and examine the impact of environmental change on animals' productivity in Germany. The research used time-series data on all the variables under research. Although some research studies focused on the effects of climate on crop and livestock productivity, none thought about the synchronized impact on agricultural crop and livestock productivity. The research discovered that temperature and relative moisture significantly affect agricultural productivity. Relative moisture was positively associated with farming productivity; the temperature has an unfavourable relationship. The research advised that government must sensitize farmers on demand to carry out smart farming to lower losses due to weather changes. The study additionally found that rainfall is positively associated with agricultural productivity. Therefore, the researchers concluded that environmental change influences agricultural production in Germany.

A study by Henderson, Godar, Frey, Börner and Gardner (2021) noted that farming is most prone to climate adjustment. According to the most recent estimates, farmers' adaptation of farm production to climate change is inevitable. The climate attributes projected to have the most direct effects on agricultural production are the surge in temperature, the change in the frequency and strength of precipitation and adverse climate phenomena, and the rise in the level of carbon dioxide available for photosynthesis. The research assesses the economic costs of environmental change in Paraguay farming production during the past forty years and examines the effects for policymakers and agricultural studies. It recommends that climate change is already there and substantially affects farming production. Farmers are required to adapt to the anticipated effects of climate change to keep on their standard of living. The adjustment of farming to environmental change entails changing crops and changes in farming methods. Policies must consider the multidimensionality of contemporary farming and the value of sustainable agricultural growth.

Kukal and Irmak (2018) argued that climate change has been a significant concern since the end of the 20th century and affects a range of economic sectors, mainly farming. The adverse effects of environmental change on farming production are necessary because agriculture is connected to food safety. Although they contribute the least to global contamination, it is approximated that many nations will be most influenced by climate irregularity. The study examines the impact of climate change on agricultural production in 4 Southern American nations from 2005 to 2017 and approximates a panel data model for farming production utilizing environment variables and economic aspects as explanatory variables. The outcomes show that variable rainfall favorably influences agricultural productivity, while the overall rise in annual mean temperature reduces farming productivity in these nations. Quantifying the influences of environmental change on agricultural productivity may assist policymakers in establishing the most effective adaptation and reduction strategies.

3.0 Research Methodology

The study adopted the cross-section research design. Questionnaires were used to collect the data. The respondents included farmers and officials in Japan's Ministry of Agriculture, Forestry and Fisheries. Descriptive and inferential statistics were used to analyze the data. The study conducted a pilot study to examine the validity and reliability of the research instruments. The presentation of the data was done using the Table and graphs.

4.0 Research Findings

4.1 Correlation Analysis

The results presented in Table 1 describe the correlation analysis

Table 1: Correlation Analysis

		Agricultural Productivity	Climate Change
Agricultural Productivity	Pearson Correlation	1.000	
	Sig. (2-tailed)		
Climate Change	Pearson Correlation	-.645**	
	Sig. (2-tailed)	0.000	0.000

The study results show that the correlation between agricultural productivity and climate change is negative and significant (r=.645, p=.000). This implies when the climate changes increase, productivity will decrease. Hence, the study results agree with the findings of Miles-Novelo and Anderson (2019), who articulated that climate change negatively affects the agricultural sector. Hussain, Huang, Huang, Ahmad, Nanda, Anwar and Zhang (2020) discovered that the recent pattern of rising temperature levels had affected agriculture in several ways, consisting of the farming and quality of rice, which is the staple food in Japan. Emadodin, Corral, Reinsch and Taube (2021) articulated that environmental change is a global problem that has a higher influence on productivity via farming production, animal production, energy and tourism.

4.2 Regression Analysis

The model fitness results are summarized in Table 2

Table 2: Model Fitness

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.315a	0.291	0.234	0.120144

The results from Table 2 depict that climate change was found to be satisfactory in explaining the agricultural productivity in Japan. This was supported by the coefficient of determination, also known as the R square of 0.291. This implied that climate change explains 29.1% of the variations in agricultural productivity in Japan.

Table 3: Analysis of Variance

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	7.58	1	7.58	149.96	.000b
	Residual	9.25	183	0.051		
	Total	16.83	184			

The results in Table 3 show that the overall model was statistically significant. The results indicate that climate change is a good predictor of agricultural productivity. This was supported by an F statistic of 149.96 and the reported p-value of 0.000, which is less than the conventional probability significance level of 0.05. Therefore, relevant authorities can work on regulating the factors that negatively affect climate change since the variable was fundamental in determining the level of agricultural productivity in Japan.

Table 4: Regression of Coefficient

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.156	0.021		7.43	0.004
Climate Change	-0.327	0.155	0.351	2.11	0.017

The study found that climate change is negatively and significantly related to agricultural productivity (β=-0.327, p=0.017). This was supported by a calculated t-statistic of 2.11, larger than the critical t-statistic of 1.96. The results implied that when the climate change deteriorates by one unit, the agricultural productivity will reduce by 0.327 units holding other factors constant. The study results concur with Ortiz-Bobea, Ault, Carrillo, Chambers and Lobell (2021), who noted that agricultural productivity is vulnerable to weather and thus negatively influences its output. The recent pattern of rising temperature levels has affected agriculture in several ways, including the farming and quality of rice, which is the staple food in Japan. Miles-Novelo and Anderson (2019) articulated that climate change negatively affects the agricultural sector. Emadodin, Corral, Reinsch and Taube (2021) articulated that environmental change is a global problem that has a higher influence on productivity via farming production, animal production, energy and tourism. Hussain, Huang, Huang, Ahmad, Nanda, Anwar and Zhang (2020) discovered that the recent pattern of rising temperature levels had affected agriculture in several ways, consisting of the farming and quality of rice, which is the staple food in Japan.

5.0 Conclusion

The study concluded that the correlation between agricultural productivity and climate change is negative and significant. This implies when the climate changes increase, productivity will decrease. Climate change was found to be satisfactory in explaining agricultural productivity in Japan. This was supported by the coefficient of determination, also known as the R square of 0.291 (29.1%). The results indicate that climate change is a good predictor of agricultural productivity. This was supported by an F statistic of 149.96 and the reported p-value of 0.000, which is less than the conventional probability significance level of 0.05. The study found that climate change is negatively and significantly related to agricultural productivity (β=-0.327, p=0.017). The results implied that when the climate change deteriorates by one unit, the agricultural productivity will reduce by 0.327 units holding other factors constant. The effect of climate change is frequent wildfires, more extended periods of drought in some regions and an increase in the number, duration and intensity of tropical storms. Climate change refers to long-term shifts in temperatures and weather patterns.

6.0 Recommendations

Based on the study's findings, it is recommended that there is a need to focus on planet-friendly investments. Individuals can spur change through savings and investments by choosing financial institutions that do not invest in carbon-polluting industries. The government needs to accomplish sensitization program awareness on cause, influence, reduction and adjustment to environmental change. The government needs to additionally urge the adoption of smart agriculture where farmers do not count on rain feed agriculture but on scientific agriculture. It should provide farmers with drought-resistant seeds and livestock to improve production and ensure food security in Japan. Technological development can decrease the unfavorable effects of weather irregularity and might affect global adaptation efforts favoring various nations. There should be an emphasis on more tree planting in the country.

REFERENCES

Arora, N. K. (2019). Impact of climate change on agriculture production and its sustainable solutions. *International Journal of Environmental Sustainability*, 2(2), 95-96. https://doi.org/10.1007/s42398-019-00078-w

Banerjee, O., Cicowiez, M., Rios, A. R., & de Lima, C. Z. (2021). Climate Change Impacts on Agriculture in Latin America and the Caribbean: An Application of the Integrated Economic-Environmental Modeling (IEEM) Platform (No. 11777). Inter-American Development Bank. https://doi.org/10.18235/0003794

Emadodin, I., Corral, D. E. F., Reinsch, T., Kluß, C., & Taube, F. (2021). Climate Change effects on temperate grassland and its implication for forage production: a case study from Northern Germany. *Journal of Agriculture*, 11(3), 23-42. https://doi.org/10.3390/agriculture11030232

Gruda, N., Bisbis, M., & Tanny, J. (2019). Influence of climate change on protected cultivation: Impacts and sustainable adaptation strategies-A review. *Journal of Cleaner Production*, 22(5), 481-495. https://doi.org/10.1016/j.jclepro.2019.03.210

Henderson, J., Godar, J., Frey, G. P., Börner, J., & Gardner, T. (2021). The Paraguayan Chaco at a crossroads: drivers of an emerging soybean frontier. *Journal of Regional Environmental Change*, 21(3), 1-14. https://doi.org/10.1007/s10113-021-01804-z

Hussain, A., Qamar, F. M., Adhikari, L., Hunzai, A. I., Rehman, A. U., & Bano, K. (2021). Climate change, mountain food systems, and emerging opportunities: A study from the Hindu Kush Karakoram Pamir Landscape, Pakistan. *Sustainabilit*y, 13(6), 30-57. https://doi.org/10.3390/su13063057

Hussain, S., Huang, J., Huang, J., Ahmad, S., Nanda, S., Anwar, S., ... & Zhang, J. (2020). Rice production under climate change: adaptations and mitigating strategies. In Environment, climate, plant and vegetation growth (pp. 659-686). Springer, Cham. https://doi.org/10.1007/978-3-030-49732-3_26

Jatoi, W. N., Mubeen, M., Ahmad, A., Cheema, M. A., Lin, Z., & Hashmi, M. Z. (2021). Building Climate Resilience in Agriculture. Springer Nature. *Journal of Agriculture*, 6(2), 17-32 https://doi.org/10.1007/978-3-030-79408-8

Khan, N. A., Gao, Q., Abid, M., & Shah, A. A. (2021). Mapping farmers' vulnerability to climate change and its induced hazards: evidence from the rice-growing zones of Punjab, Pakistan. *Environmental Science and Pollution Research*, 28(4), 419-424. https://doi.org/10.1007/s11356-020-10758-4

Kukal, M. S., & Irmak, S. (2018). Climate-driven crop yield and yield variability and climate change impacts on the US Great Plains agricultural production. *Scientific reports*, 8(1), 1-18. https://doi.org/10.1038/s41598-018-21848-2

Letcher, T. M. (2021). *Why discuss the impacts of climate change? In The Impacts of Climate Change* (pp. 3-17). Elsevier. https://doi.org/10.1016/B978-0-12-822373-4.00020-3

Miles-Novelo, A., & Anderson, C. A. (2019). Climate change and psychology: Effects of rapid global warming on violence and aggression. *Journal of Current Climate Change Reports*, 5(1), 36-46. https://doi.org/10.1007/s40641-019-00121-2

Ortiz-Bobea, A., Ault, T. R., Carrillo, C. M., Chambers, R. G., & Lobell, D. B. (2021). Anthropogenic climate change has slowed global agricultural productivity growth. *Nature Climate Change*, 11(4), 306-312. https://doi.org/10.1038/s41558-021-01000-1

Skendžić, S., Zovko, M., Živković, I. P., Lešić, V., & Lemić, D. (2021). The impact of climate change on agricultural insect pests. Insects, 12(5), 440-447 https://doi.org/10.3390/insects12050440

Thomas, A., Baptiste, A., Martyr-Koller, R., Pringle, P., & Rhiney, K. (2020). Climate change and small island developing states. *Annual Review of Environment and Resources*, 4(5), 1-27. https://doi.org/10.1146/annurev-environ-012320-083355

Yalew, S. G., van Vliet, M. T., Gernaat, D. E., Ludwig, F., Miara, A., Park, C., ... & Van Vuuren, D. P. (2020). Impacts of climate change on energy systems in global and regional scenarios. *Nature Energy*, 5(10), 794-802. https://doi.org/10.1038/s41560-020-0664-z

Zhang, Y., You, Q., Mao, G., Chen, C., & Ye, Z. (2019). Short-term concurrent drought and heatwave frequency with 1.5 and 2.0 C global warming in humid subtropical basins: a case study in the Gan River Basin, China. *Climate dynamics*, 52(7), 4621-4641. https://doi.org/10.1007/s00382-018-4398-6